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Office of the Secretary
Docketing & Service
Section

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October 24, 1979

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DOCKET NUMBER
PROPOSED RULE PR-30 et al (44FR 50012)

Mr. Samuel J. Chilk
Secretary of the Commission
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

ATTENTION: Docketing and Service Branch

Dear Mr. Chilk:

Enclosed are the comments of the American Mining Congress on (1) the proposed regulations of the Nuclear Regulatory Commission on Criteria Relating to Uranium Mill Tailings and Construction of Major Plants (proposed 10 C.F.R. 30, 40, 70, 150 and 170; 44 Fed. Reg. 50015, August 24, 1979) and (2) the first draft Generic Environmental Impact Statement on Uranium Milling (NUREG-0511, April 1979).

The American Mining Congress is a trade association whose membership includes over 500 companies involved in exploration, development and production of the essential minerals and fuel resources vital to the productive capacity and national security of the United States. Our membership includes most of the U. S. companies that currently produce or are expected to produce uranium ore concentrate necessary to help meet the present and future needs of this country.

The Nuclear Regulatory Commission is to be commended on the efforts of its staff to develop necessary and reasonable regulations relating to the licensing and operation of uranium producing facilities. As these efforts continue, the AMC and its member companies would welcome the opportunity to provide whatever further assistance is necessary to arrive at regulations that adequately protect public health and assure the necessary uranium production to help meet the energy needs and maintain the common defense and security of this country.

Sincerely, 1539 342

J. Allen Overton, Jr.

J. Allen Overton, Jr.
President

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COMMENTS BY THE AMERICAN MINING CONGRESS ON THE DRAFT GENERIC ENVIRONMENTAL IMPACT STATEMENT (GEIS) ON URANIUM MILLING (NUREG - 0511) AND ON THE PROPOSED REGULATIONS ON CRITERIA RELATING TO URANIUM MILL TAILINGS AND CONSTRUCTION OF MAJOR PLANTS (44 FED. REG. 50015, et seq.)

PARTS I & II
PART III
(BOUND SEPARATELY IN TWO VOLUMES)

FOUNDED 1897

Submitted on October 24, 1979

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AMERICAN MINING CONGRESS

Founded in 1897, the American Mining Congress is an industry association that encompasses (1) producers of most of America's metals, coal, industrial and agricultural minerals; (2) manufacturers of mining and mineral processing machinery, equipment and supplies; and (3) engineering and consulting firms and financial institutions that serve the mining industry.

Headquartered in Washington, D.C., the American Mining Congress is both a clearinghouse for information and a coordinator for action on behalf of the mining industry in the nation's capital. It keeps its members informed on matters pending in Congress, the Executive Branch and independent agencies and works for constructive policies that will best enable the mining industry to serve the needs of the nation.

As spokesman for the industry, the Mining Congress advocates measures that will promote the development of mineral resources that are vital to the nation's security and the material well-being of its people. Among its specific areas of recent and continuing concern are energy policies, taxation, environmental quality, public lands, health and safety, land reclamation and many others.

In short, it is the mining industry's eyes and ears – and its collective voice – in Washington.

The American Mining Congress is also in the vanguard of improving mining practices and equipment, particularly through its conventions and expositions. It assists and supports endeavors of mine operators and equipment manufacturers toward enhanced employee safety and health and increased efficiency of the industry.

J. Allen Overton Jr.

J. Allen Overton, Jr.
President

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October 24, 1979

Mr. Samuel J. Chilk
Secretary of the Commission
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dr. John B. Martin
Director, Division of Waste Management
Office of Nuclear Material Safety
  and Safeguards
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Gentlemen:

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Sincerely,

J. Allen Overton Jr.

J. Allen Overton, Jr.
President

1544 004

COMMENTS BY
THE AMERICAN MINING CONGRESS
ON THE
DRAFT GENERIC ENVIRONMENTAL IMPACT STATEMENT (GEIS) ON URANIUM MILLING
(NUREG-0511)
AND ON THE PROPOSED REGULATIONS ON CRITERIA RELATING TO URANIUM MILL TAILINGS AND CONSTRUCTION OF MAJOR PLANTS
(44 FED. REG. 50015, *et seq.*)

Prepared by the AMC Uranium Environmental Subcommittee
Submitted on October 24, 1979

ORGANIZATION OF COMMENTS

The comments by the American Mining Congress (AMC) on the draft Generic Environmental Impact Statement (GEIS) on Uranium Milling (NUREG-0511) and on the proposed regulations on Criteria Relating to Uranium Mill Tailings and Construction of Major Plants (44 Fed. Reg. 50015, et seq.) are divided into three parts: 1) Part I, an Executive Summary presenting AMC's basic conclusions and a broad overview of the major points; 2) Part II, General Comments presenting discussion of these major points with examples from AMC's specific comments to demonstrate these points; and 3) Part III, Specific Comments presenting the detailed analysis of particular portions of the draft GEIS and the proposed regulations.

PART I

EXECUTIVE SUMMARY OF COMMENTS BY
THE AMERICAN MINING CONGRESS
ON THE
DRAFT GENERIC ENVIRONMENTAL IMPACT
STATEMENT (GEIS) ON URANIUM MILLING
(NUREG-0511)
AND ON THE PROPOSED REGULATIONS ON
CRITERIA RELATING TO URANIUM MILL TAILINGS
AND CONSTRUCTION OF MAJOR PLANTS
(44 FED. REG. 50015, *et seq.*)

Prepared by the AMC Uranium Environmental Subcommittee
Submitted on October 24, 1979

PART I

EXECUTIVE SUMMARY

AMC'S BASIC CONCLUSION CONCERNING THE DRAFT GEIS

The stated purpose and principal objectives of the Nuclear Regulatory Commission (NRC) in undertaking preparation of the draft GEIS are to assess the environmental impacts of uranium milling operations to determine what, if any, changes are required in regulation of these operations with particular emphasis on mill tailings disposal and mill decommissioning. See Draft GEIS, Summary, p.2; 41 Fed. Reg. 22430 (June 3, 1976). Any proposed regulatory changes should be based on and supported by data and analysis in the GEIS. The *need* for each particular regulatory action should be presented in the GEIS. See, Draft GEIS, Summary, p.2; 44 Fed. Reg. 50012, 50017 (Aug. 24, 1979).

The draft GEIS fails to achieve its stated purpose and objectives.

It should be revised and reissued in draft form and resubjected to the necessary public scrutiny. The draft GEIS does not demonstrate the requisite need for the proposed regulations; it merely addresses the *effects* of the proposed rules.

Comparison of the proposed new licensing criteria with prior NRC policies contained in Regulatory Guides, Branch Positions and Performance Objectives makes it appear that the draft GEIS is an attempt to legitimatize these policies which have never undergone proper regulatory scrutiny.

Any elevation of these policies to the level of regulatory requirements must be supported by sound, state-of-the-art scientific analysis. The draft GEIS presents no such analysis but rather, assumes the validity of these prior NRC policies. The regulatory conclusions in the proposed rulemaking are, therefore, not well founded or necessary.

ANALYTICAL, EVIDENTIARY AND METHODOLOGICAL DEFICIENCIES IN THE DRAFT GEIS

The data presented in the draft GEIS in support of its regulatory proposals deal mainly with the potential effects of those proposals rather than the need for the proposals. Much of the data is flawed. Risks are substantially overestimated and costs are just as substantially underestimated. Moreover, the draft GEIS does not contain adequate cost effectiveness analyses of the proposed regulations.

The risks and costs are not correctly estimated because the analytical methods employed continually compound errors caused by inaccurate or conservative assumptions. This continual compounding results in a total error that is far greater than the sum of the individual errors.

A. The Potential Radiological Impact on Public Health and Safety Attributed to Uranium Milling Processes in the Draft GEIS is Grossly Exaggerated

The draft GEIS relies on potential adverse radiological effects to justify one of its most stringent regulatory proposals -- a radon flux limit of 2 pCi/m^2sec above natural background levels and a minimum of three meters of cover material on reclaimed tailings. In reality the proposals are based on a preconceived NRC objective -- to return tailings disposal sites "to conditions reasonably near those of the surrounding environment," (See, 44 Fed. Reg. 50017) -- rather than on scientific analyses that demonstrate a need to impose such stringent requirements.

The evidence put forward in the draft GEIS is unreliable because of the analytical approaches employed. The draft GEIS uses a "conservative" or "worst case" approach to modeling and interpreting data in almost all cases. This creates a major potential for error. When this general approach is combined with other errors the compounding effect grossly distorts what can be expected in the real world.

Four examples where the draft GEIS compounds errors by its analytical approach are discussed below.

Radon

The treatment of radon emanation from tailings piles and its potential impact on public health and safety in the draft GEIS is flawed by a series of errors.

One such error involves assumptions made regarding the potential health effects predicted from the 1972 BEIR Report data. The draft GEIS improperly modifies the absolute risk coefficient developed in the BEIR Report and fails to adequately consider the relative risk model in light of recent evidence which indicates that this relative risk model best describes the data. The draft GEIS develops an unrealistically high estimate of the benefits of radon control by averaging the absolute and relative risk estimators and treating this average as an absolute risk estimator.

Perhaps the most important flaw in the way the draft GEIS uses the BEIR Report risk models involves their application to low-level radiation exposures which would be experienced by the general population. The BEIR Report data were partially derived from studies of uranium and fluorspar miners exposed to concentrations of radon which were orders of magnitude above those to which the general population will be exposed. BEIR Report conclusions regarding linear dose-effect relationships and numerical risk estimates are improperly applied to the general population in view of the vast difference in levels of exposures.

The draft GEIS should utilize the most recent and best available information on dose-response models, risk estimates and carcinogenic co-factors to calculate the benefits of radon emission controls. It does not. The series of assumptions and factors (which are inaccurately and unduly biased to overstate expected health effects to the general population from radon emanation) when multiplied together result in an overestimate of the risk by a factor of *300 to 6,000*.

The radon emission controls proposed in the draft GEIS ($2 pCi/m^2 sec$ above natural background levels and a minimum of 3 meters of cover material) are based on NRC staff philosophy to reduce maximum radon exposures to levels slightly above the *average* from natural sources. It ignores observed distributions of radon in nature which are log-normal. It *averages out* all of the variability of the real world in an attempt to assure that human controlled sources of radon will be reduced to average natural levels. The actual distribution (or range) of radon impacts from different natural sources should be compared with human controlled sources.

From a purely radiological standpoint (not considering cost effectiveness) a radon emission limit in the range of 25-30 pCi/m^2sec above natural background levels appears reasonable. The land area of the U.S. which exceeds this range naturally is at least ten times the total area of all tailings piles from all mills projected by the year 2000.

Use of Models

The draft GEIS uses several models to predict the future potential effects on the environment of uranium milling operations. Models can be an effective tool but any conclusions based on them must be tempered by site specific real world facts. The draft GEIS does not do this. Additionally, in far too many instances, the draft GEIS does not employ correct or state-of-the-art assumptions in the models used. This creates biases that are unrealistically conservative.

Model Mill -- The model mill used in the draft GEIS is too limited in terms of the variations which exist in locations and operations of existing or future uranium mills. Many of the assumptions relied upon are either out of date or otherwise inaccurate. The overly conservative biases built into the model mill concept in the draft GEIS result in an overstated radiological impact from real milling operations.

UDAD Code -- The conservative biases in the model mill concept are further compounded by the overly conservative assumptions or modeling methods used in the uranium dispersion and dosimetry (UDAD) code. The UDAD Code is based on a synthesis of submodels, many of which do not accurately represent the physical processes they are intended to model or are not state-of-the-art modeling for those processes.

Uncertainties are inherent in the estimates provided by each submodel. Some of these uncertainties have been identified and quantified by AMC as being orders of magnitude from reality. To protect against such uncertainty the Code employs overly conservative assumptions or modeling methods in many submodels. This conservatism is compounded when the results of one submodel are used as input to other submodels. The result in the dispersion, deposition and external dose submodels is that external dose equivalents at near receptors are overestimatd by a factor between 40 and 600.

Prior to publication of a revised draft GEIS the UDAD Code should be modified.

B. Inadequate Cost Consideration

The draft GEIS describes some of the economic consequences of the proposed licensing requirements. Unfortunately much of the information is incomplete, inaccurate or inappropriate. Accurate economic cost data is essential to any meaningful cost effectiveness analysis. Costs will affect current and future production of uranium and the cost to consumers of electricity, now and in the future. Beyond economic costs, consideration of the social and environmental costs of the proposed regulatory action is essential and mandated by federal law.

The basic approach in the draft GEIS is one of indifference to accurate cost estimates because, whatever the costs, they are judged to be within a range that is considered reasonable when compared with the perceived benefits. The draft GEIS assumes that detailed engineering and detailed cost estimating is not warranted. This attitude towards costs and cost data has led to serious cost underestimation.

Throughout the draft GEIS, the argument is made that the estimated costs are reasonable because they represent only a small fraction of the price of yellowcake or the cost of producing electricity. This analysis is unacceptable. A small incremental cost per kilowatt multiplied by a very large number of kilowatts results in a large absolute dollar burden on society. The costs of compliance with certain of the proposed licensing criteria are truly significant and will noticeably increase the public's utility bills if these criteria are promulgated in their present form.

When addressing the question of risk, the draft GEIS consistently takes the "worst case" or "conservative" approach. On the other hand, when addressing the question of cost, the "best case" is consistently used. Quantities, unit costs, and project scope are frequently underestimated or ignored resulting in significant bottom line errors in cost calculations.

The [illegible] estimates in the draft GEIS are not sufficiently accurate or complete for use in any meaningful cost effectiveness analysis. The draft GEIS should be redrafted to include accurate and complete data that will reflect the actual economic, environmental, and social costs that will result from any proposed licensing requirements.

C. Absence of Rigorous Cost Effectiveness Analyses as the Mechanism for Selecting Proposed Licensing Criteria

NRC's responsibility in regulating the various activities involved in the nuclear fuel cycle necessarily includes examination of the social, environmental and economic aspects of these activities in the regulatory process. Each of the Commission's regulatory actions, and particularly its licensing criteria to be applied during uranium mill licensing reviews, should be premised on a rigorous cost effectiveness analysis. Any proposed regulatory criterion must be derived from application of a cost effectiveness analysis rather than an arbitrary selection process which is thereafter studied to justify the result already reached.

Cost effectiveness analyses must be done on an incremental basis so that each increment of benefit -- in this instance, health risk reduction -- is analyzed in relation to the associated increment of cost. Then a reasonable standard of an acceptable cost per benefit unit must be applied to the incremental cost and beneift figures to determine the appropriate level of control.

When benefit (or risk reduction) is expressed on a per year basis, as it has been in the draft GEIS in health risk per year terms, a realistic period of integration of these benefits must be applied. This integration period must be set not only in recognition of the period over which benefits are anticipated but also in recognition of the future benefits foregone as a result of commitment of funds and resources today. There must also be a realization of the time limits on our ability to make rational predictions about future social conditions, knowledge, and technology. Integration over one hundred years appears reasonable; the utility of the analysis diminishes rapidly as the integration period is extended beyond one to a few hundred years.

The draft GEIS makes virtually no attempt to premise the proposed licensing criteria on such cost effectiveness analyses. As discussed above, AMC's basic conclusion is that these criteria are the result of previously determined NRC policy and guiding principles. These policies and principles were established without meaningful opportunity for public input and without any reasonable cost effectiveness analysis.

For instance, we have carefully examined the draft GEIS discussion of proposed criterion 6 concerning reduction of the radon exhalation rate from tailings disposal areas (after milling operations cease) to a calculated 2pCi/m^2sec above natural background levels. The draft GEIS admits that other levels such as 10, 20, 30, or 100 pCi/m^2sec were not analyzed as options to the 2pCi/m^2sec limit because these other levels would not "meet the simple objective of returning disposal sites to conditions which are reasonably near those of [the] surrounding environment." Draft GEIS, Summary p. 17, Chapter 12, p. 12-17.

Our analysis (even using the draft GEIS risk and cost estimates which are far from accurate) shows that the cost per health effect averted to reach the $2pCi/m^2sec$ level would range from $8 million to $24 million for the cover materials mentioned in the draft GEIS. These figures are wholly out of proportion to costs devoted to averting health risks under any other federal regulatory program. When cost and risk figures more accurate than the draft GEIS figures are used, the cost of achieving a $2pCi/m^2sec$ above background emanation rate exceeds $100 million for all the types of cover material discussed in the draft GEIS.

This clearly demonstrates the critical importance of using rigorous cost effectiveness analyses to select proposed regulatory requirements. Based on an accurate reassessment of risks and costs, such analyses should be included in a new draft GEIS published for public scrutiny prior to any regulatory changes.

LACK OF FLEXIBILITY

NRC should establish, from scientific data, performance standards rather than rigid design requirements. Such standards could set exposure limits to be met by every operation, while allowing each company to meet these standards using the methods that are most suitable in each site specific situation. The scientific data on which such standards must be based is the critical factor in establishing any regulations. This approach allows flexibility in meeting the standards and should be used by NRC in regulating uranium milling.

Since uranium mills do have significant operational differences it is important that any licensing regulations take into account the site specific variations. Uranium milling operations in the United States may have some generic similarities, but processing and disposal factors vary considerably from site to site. Actual production is different even at mills that are in close proximity to each other. The industry feels strongly that any licensing standards or regulations should (1) assure the adequate protection of health and (2) allow each operator to meet the standards using the methods and materials that are most appropriate and cost effective for the particular situation. It is important that the regulatory requirements be flexible.

The approach taken in the draft GEIS and in the proposed regulations does not incorporate the necessary flexibility. Although the draft GEIS continuously stresses the importance of flexibility and the need to consider site-specific factors, the proposed licensing criteria are quite rigid. The proposed regulations contain positive and specific statements as to what requirements should be imposed.

The proposed criteria, if finalized, will most assuredly become unofficial "absolutes" in the issuance of mill licenses, both by NRC and by agreement states. In the evolution of the permit process, the NRC policy positions from which the proposals were derived will become the minimum requirements for all licenses. Site-specific consideration will disappear and any semblance of cost-effective management techniques will be lost.

Once the criteria have been used in a few licenses, the NRC and the Agreement states may be forced to defend themselves in litigation or in agency proceedings for not strictly adhering to the criteria in all cases.

The proposed criteria will stifle the development of new mining technology which could reduce adverse environmental impacts.

If the uranium industry in this country is forced to use a limited number of defined techniques, production may be impossible in some situations. Also, costs may be needlessly increased and there will be no incentive to develop and use new, improved mining and disposal techniques.

When the GEIS is redrafted, it should specifically define the public health goals which NRC plans to achieve, and explain how these goals were developed. Operators may then select the most cost effective methods of meeting these goals, taking into consideration site-specific conditions. The flexibility provided in achieving performance standards will protect public health, maximize U.S. production of uranium, minimize production costs and encourage new and improved mining and disposal technology.

THE PREMATURE AND POTENTIALLY CONFLICTING NATURE OF THE PROPOSED REGULATIONS

NRC is acting prematurely in proposing regulations at this time to cover the various areas identified in the draft GEIS. If promulgated in the near future, these proposed regulations will require the uranium milling industry to make major plans and commitments to meet one set of standards now, only to have the standards changed in response to anticipated Environmental Protection Agency (EPA) standards.

NRC should recognize that Section 275 of the Atomic Energy Act, 42 U.S.C. 2022, requires EPA to promulgate standards covering uranium mill tailings by May, 1980. The standards are to have general application for the protection of public health, safety and the environment from radiological and non-radiological hazards associated with processing, possession, transfer and disposal of mill tailings. The Act contemplates that standards first be developed by EPA and then, rules be promulgated by NRC, rather than the order of events currently being proposed. Because of the statutory requirement of public participation in the development of EPA's standards, neither NRC, EPA nor anyone else can presently anticipate EPA's final standards. In this regard, it should also be noted that the published listing of information EPA intends to rely on in developing the standards is by no means limited to the information contained in the draft GEIS. (See 44 Fed. Reg. 33433).

The promulgation of regulations by NRC prior to publication of EPA's standards may force the uranium milling industry to make expenditures necessary to meet the NRC requirements and then repeat the process to comply with those established by EPA. These unnecessary expenditures would be inflationary. It is hoped that, before the NRC decides to promulgate regulations on its present timetable, it will first consider the requirements of Executive Order 12044.

PART II

GENERAL COMMENTS BY
THE AMERICAN MINING CONGRESS
ON THE
DRAFT GENERIC ENVIRONMENTAL IMPACT STATEMENT (GEIS) ON URANIUM MILLING
(NUREG-0511)

AND ON THE PROPOSED REGULATIONS ON CRITERIA RELATING TO URANIUM MILL TAILINGS AND CONSTRUCTION OF MAJOR PLANTS
(44 FED. REG. 50015, *et seq.*)

Prepared by the AMC Uranium Environmental Subcommittee

Submitted on October 24, 1979

AMC'S BASIC CONCLUSION CONCERNING THE DRAFT GEIS

The draft GEIS sets forth its purpose as follows:

> ". . .the purpose of the statement would be to assess the potential environmental impacts of uranium milling operations, in a programmatic context, including the management of uranium mill tailings and to provide an opportunity for public participation in decisions on any proposed changes in NRC regulations based on this assessment." [Emphasis added] (Draft GEIS Vol. 1, p. 2)

In support of the stated purpose, the principal objectives of the statement are set forth as follows:

1. "To assess the nature and extent of the environmental impacts of uranium milling in the United States from local, regional, and national perspectives on both short-term and long-term bases, to determine what regulatory actions are needed;

2. More specifically, to provide information on which to determine what regulatory requirements for management and disposal of mill tailings and mill decommissioning should be; and

3. To support any rulemakings that may be determined to be necessary." [Emphasis added.] (Draft GEIS, Vol. 1 p. 2).

Regrettably, the draft GEIS fails to achieve its stated purpose and objectives.

Any "programmatic" assessment of the "nature and extent of environmental impacts" of uranium milling, which is specifically designed to "provide information" on the regulatory requirements for management and disposal of mill tailings and mill decommissioning, can only support rules and regulations if that assessment demonstrates a need for such regulatory action. If the assessment of impacts fails to demonstrate such a need, then any regulations based upon the assessment would be nothing more than regulation for regulation's sake -- a concept that is not currently acceptable in the United States. See, Executive Order 12044 (43 Fed. Reg. 12661). It is also true that any such assessment of impacts must be based on sound scientific, state-of-the-art methodologies and information if it is to establish a credible need for government regulatory action.

The draft GEIS makes no attempt to discuss or substantiate the need for the proposed regulatory conclusions set forth in Chapter 12 of the GEIS and in proposed amendments to 10 CFR Part 40 (44 F.R. 50012 _et_. _seq_.) Rather, the draft GEIS discusses only the potential _effects_ of its proposed regulatory conclusions. The scientific and pseudo-scientific evidentiary base relied upon in the draft GEIS to evaluate the potential effects of the proposed regulatory criteria is so deficient that it cannot support that evaluation much less establish a need for such regulatory actions. Instead of demonstrating the need, if any, for the proposed regulatory changes the draft GEIS _assumes_ the need.

The assumed need bears a remarkable resemblance to guidance contained in existing NRC Regulatory Guides, Branch Positions and Performance Objectives. These NRC guides, positions or objectives were not designed or intended to be substitutes for regulations, and compliance with them was not intended to be mandatory. Thus, they represent conclusions of the NRC staff which have not yet been subject to any of the required rulemaking procedures. (See, Part III, Item G). In short, there has been no need established to justify or validate them. Therefore, the draft GEIS appears to be nothing more than an attempt to validate prior untested views by incorporation of those views into an alleged programmatic assessment of the environmental impacts of uranium milling operations. This attempt is not sound on a scientific, logical or legal basis. This document is not consistent with its stated purposes and objectives, and therefore its regulatory conclusions are without merit.

NRC should prepare and publish for public comment a new revised draft GEIS adequately demonstrating the scientific need for any proposed regulatory changes.

ANALYTICAL, EVIDENTIARY AND METHODOLOGICAL DEFICIENCIES IN THE DRAFT GEIS

As noted above, the data presented in the draft GEIS in support of its regulatory conclusions deals mainly with the potential effects of those conclusions rather than the need for such conclusions. Unfortunately, much of this data is flawed by certain major deficiencies. The draft GEIS substantially overestimates risks, underestimates costs and fails to make a cost effectiveness analysis of the proposed regulatory criteria.

The analytical methods used by the NRC in the draft GEIS tend to compound errors with the result that NRC's conclusions are often out of touch with reality. In the regulatory or scientific context (and particularly where the two are intimately interrelated) a series of errors or inadequacies can be compounded and will result in a total error that is far greater than the sum of the individual errors. As a result, the draft GEIS seriously overstates the risks (for example, radiological risks associated with radon) of uranium milling operations to the general public; and, just as seriously understates the actual costs of the NRC's proposed regulatory program which is allegedly based on its conclusions about those radiological risks.

Furthermore, the draft GEIS does not premise each of the proposed regulatory changes on a rigorous cost effectiveness analysis. Any regulatory actions must be developed from the conclusions of such analyses in order that any regulatory action will have a properly demonstrated basis and purpose and meet the objectives of the draft GEIS.

A. The Potential Radiological Impact on Public Health and Safety Attributed to Uranium Milling Processes in the Draft GEIS is Grossly Exaggerated

As noted, the draft GEIS fails to support the need for the proposed regulatory changes. For example, the draft GEIS apparently relies on potential adverse radiological effects to justify the stringent regulatory proposals relating to control of radon emanation from tailings piles. In fact, the justification for the three meters of cover on reclaimed tailings and for the radon emanation limit of 2 pCi/m^{2}sec is not based on scientific evidence but on a preconceived NRC performance objective -- the objective of returning the tailings disposal sites "to conditions which are reasonably near those of the surrounding environment." (Draft GEIS, Summary, page 17; 44 Fed. Reg. 50017). This lack of adequate evidentiary underpinning is symptomatic of the failure of the draft GEIS to fulfill its purpose and objectives.

The analytical approach used in the draft GEIS undermines the validity of the evidence that is presented. The term "conservative" is used frequently throughout the draft GEIS and its Appendices. This term generally connotes a particular assumption or line of reasoning that will yield a result (such as an exposure or health effect) which is in some degree higher than that which may be experienced in the real world. Some degree of such "conservatism" is a justifiable regulatory assumption when great uncertainty exists in calculations or data since it is better to err within reason on the high side in predicting exposures of health effects. However, judgment must be used to determine those situations where "conservative" factors are justified and the level of conservatism which is reasonable in light of state-of-the-art knowledge. As NRC has stated in Plan for Reevaluation of NRC Policy on Decommissioning of Nuclear Facilities (NUREG-0436)(December 1978),

> the risk involved from uranium mill tailings, particularly with regard to the long-term considerations, has not yet been fully or adequately defined and is still subject to differing opinions among the scientific community and the public.

Applying "conservative" or "worst case" assumptions across the board creates a major potential for error. When this general approach is combined with other errors the compounding effect will grossly distort what can be expected in the real world. The explanation and the evaluation of radiological risks to public health and safety set forth in the draft GEIS suffer in the extreme from this malady.

Radon

The assessment of radon emanation and its impact on public health in the draft GEIS is flawed by a series of significant errors. One involves the use by the draft GEIS of data from the 1972 BEIR Report in making certain assumptions regarding the health effects from irradiation. A series of assumptions, modifications and misapplications of BEIR Report data in the draft GEIS leads to serious overstatement of radiological risks. For example, the document inappropriately modifies the absolute risk coefficient for lung mortality stated in the BEIR Report from 1.3 to 2.0 mortalities/10^6 person year/rem. (see Part III, Item A.1.)

Additionally, the draft GEIS does not adequately consider the BEIR Report data in terms of the relative risk coefficient. The absolute risk model implies that each increment of exposure will produce the same total biological effect (e.g. cases of lung cancer) regardless of the actual level of exposure or the presence of other carcinogens. This is the only truly linear model for the dose-response relationship. Recent analyses of lung cancer incidence among uranium miners indicate that the relative risk model best describes the data.

The draft GEIS obtains an unrealistically high estimate of the benefit of radon control by averaging the absolute and relative risk estimators derived from uranium miners and treating this average as an absolute risk. It has ignored the recent evidence that indicates that lung cancer can be best described by the relative risk model, and has ignored the important implications and proper application of the relative risk model. (See Part III, Item A.2., pp. 4-8)

Perhaps the most important problem with the way the draft GEIS uses BEIR Report risk models involves their application to low-level radiation exposures expected for the U.S. population. The BEIR Report data were partially derived from studies of miners exposed to high levels of radiation in uranium and fluorspar mines. Those miners were exposed to concentrations of radon and its decay products that were orders of magnitude above those to which the general population will be exposed. The President's Interagency Nuclear Waste Review Group specifically recognizes this problem as follows:

> "The area of evaluating the impact of radon emissions is complicated by uncertainties in effects and dosimetry. Much of the problem related to effects assessment is due to the small base of epidemiology which is primarily based on uranium miners. These individuals possess many characteristics that differentiate them from members of the general population; and therefore the extrapolation is different." Report to the president by the Interagency Review Group on Nuclear Waste Management, Appendix II, p. 15 (1979).

The draft GEIS inappropriately applies the conclusions of the BEIR Report regarding linear dose-effect relationships and numerical risk estimates derived from the data on uranium miners to the general population in view of the fact that the level of exposure is in no way comparable. Such estimates tend to ignore the very real contributions of carcinogenic co-factors to the total risk of lung cancer. The draft GEIS should utilize the most recent and best available dose-response models and risk estimates for calculating the benefits of radon emission controls. The implications of the relative risk model with regard to carcinogenic co-factors, and in particular the initiator-promotor models of carcinogenesis, should be recognized and utilized. (See Part III, Item A.1. and A.2.).

Implicit in the use of BEIR Report data in the draft GEIS as described above is the assumption that the relationship between mortality from excess lung cancer due to exposure to radon and mortality from competing causes of death remains constant. At low exposures, it is not reasonable to assume that the relationship of mortality from excess lung cancer and from competing causes of death will be the same as at the very high levels of exposures experienced by the miners. At the low dose levels from a tailings pile, the induction-latent period for the appearance of lung cancer among those exposed can be significantly longer than among the miners studied. Longer induction-latent periods open the way for competing causes of mortality to represent a higher percentage among the public than it has among miners whose high exposure and smoking habits cause a shorter induction-latent period. (See Part III, Item A.1.).

Thus, the series of assumptions and factors which are unduly biased to overstate expected health effects to the public from radon emanation from uranium tailings piles, when multiplied together, result in an overestimate of the risk by a factor of 300 to 6000. (See, Part III, Item J, Testimony of Langan W. Swent).

The draft GEIS treatment of radon emission criteria ignores the normal criteria for establishing radiation exposure controls, i.e., limiting of individual exposures to established dose limits and population exposures to levels that are as low as reasonably achievable (ALARA), taking into account all social and economic factors. Instead, the draft GEIS proposes radon controls on the basis of NRC staff judgments and philosophy that would reduce the maximum exposures to levels that are slightly above the <u>average</u> from natural sources. The control level proposed in the draft GEIS would protect the hypothetical individual living in a residence built over tailings to an exposure rate that is less than one-tenth of that to which at least 100,000 persons in the U.S. are currently exposed in their homes from natural sources.

The draft GEIS continually compares radon emissions from mill tailings with average radon fluxes and concentrations. It ignores the observed distributions of radon in nature and the fact that these distributions are log-normal. Measured natural indoor radon concentrations in the U.S. range as high as 4800 pCi/m^3, while in other countries even higher concentrations have been reported. Based on the observed distributions, it is likely that at least 100,000 persons in the U.S. live in natural concentrations exceeding 9600 pCi/m^3. Yet the draft GEIS proposes a limit for tailings pile emissions that would limit the maximum individual exposure to a concentration of 720 pCi/m^3. It averages out all of the variability of the real world in an attempt to assure that human controlled sources of radon will be reduced to average background levels. This approach ignores the actual distribution (or range) of radon impacts from different natural sources with which the impacts of human controlled activities should be compared. (See Part III, Item A.2)

Cost effectiveness aside, radon emission limit of at least 25-30 pCi/m^{2}sec above natural background levels appears reasonable based on the low risk to any individual (as well as to the general population). Further, the land area of the U.S. that exceeds this range naturally is at least 10 times the total area of all tailings piles from the model mills projected to exist by the year 2000.

Use of Models

The draft GEIS uses a series of models to attempt to predict the future potential effects on the environment of uranium milling operations. A number of major conclusions and judgments presented in the draft GEIS are based in part on the application of these models. In some cases, modeling can be an effective regulatory tool. In this case it could be a reasonable starting point. Unfortunately, in far too many instances, the draft GEIS uses incorrect or non state-of-the-art assumptions which create biases in the models developed. In some cases unrealistically conservative assumptions upon which the models are based make the results obtained from using the models misleading. The draft GEIS relies too heavily upon the modeling concept without blending the results of modeling with site specific information from real world mills.

Model Mill -- The locations and operations of actual producing mills do not fall into the neat little categories described in the draft GEIS. The "cookbook" approach adopted in the GEIS does not come close to describing the variations which exist and which must be taken into account in identifying and evaluating locations and operations of existing or future mills. The estimate of 82 mills in operation by the year 2,000 is considered high. Fifty mills would be a more realistic estimate based on more recent electric energy demand projections.

Many of the factual assumptions regarding the operational capabilities of the model mill are out of date or inaccurate. For example, in Section 5.1 (Draft GEIS, p. 5-1), the draft GEIS assumes an ore pad will occupy 20 acres, have a mean ore storage time of 10 days and have a feed rate to the mill of 2,000 ST per day. The numbers are unrealistic and would have a conservative bias on source terms for radiological impact. If the ore storage pad is 20 acres, it would have an approximate storage capacity of ten 60,000 ST stockpiles or almost enough ore for one year of operation. A ten day supply of ore would occupy an area of only one acre, including an allowance for haulage roads.

In another section (Draft GEIS Section 7.1.2.1., p. 7-2) the draft GEIS assumes that a scrubber totally fails to function for 8 hours during a night shift and that pressure goes unchecked for the entire shift. The presumed result is the release to the environment of approximately 11 kg (25lb.) of insoluable uranium oxide particles all of which are in the respirable size range.

In reality the scrubbers in most mills operate under a variety of controls which have a designed failsafe capability. This would effectively reduce the probability of a total release to the environment. The assumption that all 11kg(25lb.) of yellow cake is in the respirable size range of less than 5 microns is incorrect. In actuality less than 10% would be in a respirable size range when ore is passed through a roll crusher to make certain that it will all pass through a four mesh screen at the sampling plant. The result is a dry, granular material, which is kept relatively coarse in order to minimize dust in handling. As a result, the dose to the nearest residents would be less than 10% of the 50 year dose commitment predicted in the draft GEIS (or approximately 8.6 mrem).

Section 6.2.8.2.4.4, (Draft GEIS, p. 6-31) discusses compliance with EPA's 40 CFR Part 190 regulations. The calculations presented and conclusions drawn are all based on the model mill, and, therefore, have no validity with respect to a real uranium mill. To have any value the calculations must be redone for each real uranium mill using the appropriate specific site data. Different conclusions may be drawn for each mill depending on the specific data from the mill and the results of the calculations. The results of the calculations for the "model mill" and the conclusions drawn from their results cannot and should not be used to determine whether or not a specific real uranium mill or mills as a group can or cannot meet the EPA regulation.

The NRC recognizes the lack of a scientific basis and other inherent flaws in 40 C.F.R. Part 190 as evidenced by its fierce opposition and criticism of it (see Part III, Item I). The AMC and others also criticized the proposed regulation for many of the same reasons. In spite of the defects in the regulation, however, NRC must now interpret 40 C.F.R. Part 190, such as it is, to allow the flexibility necessary to protect public health while assuring the production of uranium in this country to meet the current and future energy needs and to maintain our common defense and security. See, Section 1(a) of the Atomic Energy Act, 42 U.S.C. 2011.

Since the NRC has the duty to implement and enforce the EPA regulation (see 40 Fed. Reg. 23420, May 29, 1975), it has the important responsibility of interpreting it. The Commission must use its broad discretion to determine a reasonable way to apply the regulations to U.S. uranium mills that vary significantly as to their size, ore characteristics, location, proximity to ground and surface water, proximity to population centers, and other factors.

The failure of the draft GEIS to define the model mill in terms of a series of "probable ranges" for production, ore grades, environmental or dose effects and controls makes the model mill too restrictive when considered in relation to real milling activities. Conservative assumptions built into the model mill and model region create an inherent bias on the high side when those models are compared to real mill operations. In general, the predicted health effects due to the model uranium mill(s) are a miniscule percentage of the total background health effects in the various categories analyzed in spite of the compounding of all the conservative assumptions involved. If the predicted health effects were recalculated after elimination of all these conservative assumptions, the results would be at least an order of magnitude less than those contained in the draft GEIS.

UDAD Code -- These conservative assumptions in the model mill concept are compounded by additional conservative assumptions included in the uranium dispersion and dosimetry (UDAD) code. The UDAD Code was used in the draft GEIS to estimate individual and population dose commitments for the operational base case and alternative mill scenarios. It was also used in evaluating the effectiveness of alternative tailings pond management plans during and after reclamation.

Because of the complexity of the systems analyzed, there is an inherent need for a computer simulation model for these evaluations. However, the UDAD Code, in its current configuration, is not an exact enough tool to be used for these purposes.

The UDAD Code is a synthesis of a number of submodels. Analysis of the supporting documents for these submodels raises two major issues:

1. Several of the submodels either do not accurately represent the physical processes they are intended to model or are not state-of-the-art for modeling those particular processes. This is particularly true for the submodels used to estimate source terms, to account for dispersion and deposition, to calculate ground concentrations, and to calculate vegetation, meat and milk radionuclide uptake.
2. Uncertainty is inherent in estimates provided by each of the submodels. Although never quantified in the draft GEIS documentation, some cases have been identified where this uncertainty is <u>orders of magnitude</u>. To account for this uncertainty, conservative assumptions and/or conservative methods of modeling have been incorporated in many of the submodels to assure that risks to the public are not underestimated.

Conservatism within the Code is compounded when the conservative results of one submodel are used as input to other conservative submodels. UDAD Code dose calculations are conservative by several orders of magnitude depending on specific situations. For example, conservatisms inherent in only the dispersion, deposition and external does submodels cause external dose equivalents at near receptors to be overestimated by a factor between 40 and 600. Use of the Code as the final and exact source of dose estimates and as a basis for regulatory actions, as in the draft GEIS, does not represent use of "best available technology". Prior to publication of a revised draft GEIS the UDAD Code should be modified. Priorities for submodel modifications and for further research should be established by conducting a sensitivity analysis of the code. Such an analysis would allow the NRC to identify those critical parameters which most affect Code output. (See Part III, Item A.3.).

B. Inadequate Cost Consideration

The draft GEIS describes some of the economic consequences of the proposed licensing requirements. Unfortunately much of the information is incomplete, inaccurate or inappropriate. Accurate economic cost data is essential to any meaningful cost benefit analysis. Costs will affect current and future production of uranium and the cost to consumers of electricity, now and in the future. Beyond economic costs, consideration of the social and environmental costs of the proposed regulatory action is essential and mandated by federal law.

The basic approach in the draft GEIS is one of indifference to accurate cost estimates because, whatever the costs, they are judged to be within a range that is considered reasonable when compared with the perceived benefits. The

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draft GEIS assumes that detailed engineering and detailed cost estimating is not warranted. This attitude towards costs and cost data has led to serious cost underestimation.

Throughout the draft GEIS, the argument is made that the estimated costs are reasonable because they represent only a small fraction of the price of yellowcake or the cost of producing electricity. This analysis is unacceptable. A small incremental cost per kilowatt multiplied by a very large number of kilowatts results in a large absolute dollar burden on society. The costs of compliance with certain of the proposed licensing criteria are truly significant and will noticeably increase the public's utility bills if these criteria are promulgated in their present form.

When addressing the question of risk, the draft GEIS consistently takes the "worst case" or "conservative" approach. On the other hand, when addressing the question of cost, the "best case" is consistently used. Quantities, unit costs, and project scope are frequently underestimated or ignored resulting in significant bottom line errors in cost calculations.

For example, in computing the costs of tailings management alternatives, the draft GEIS unrealistically assumes that no unduly difficult earthwork will be required. In selecting unit costs for various earthwork procedures, the draft GEIS consistently chooses values at the lower end of its projected cost range. Unit costs are frequently low by a factor or 2 or 3 or more. The use of such low unit costs results in major across the board errors in computation of the costs of alternative mill tailings management programs.

The draft GEIS also assumes that cover material will be available on site, free of cost. AMC is not aware of any mill site that has all of its cover requirements readily available on the site for excavation. Consideration must be given to probable costs involved in purchasing and hauling the cover material substantial distances. Even if it is assumed, as does the draft GEIS, that the dirt is free on site, additional costs will be incurred in reclaiming and revegetating the site from which the soil is taken.

As set forth in more detail in Part III, Item C.3., the draft GEIS ignores costs directly attributable to the regulatory process such as administrative and legal costs and interest costs during construction. It fails to give adequate consideration to the effects of inflation and the effect of potential changes in future EPA regulations. The costs for decommissioning the mill site are underestimated by a large factor. The draft GEIS unrealistically assumes that buildings and machinery can be removed at no cost to the mill operator. Other important costs such as increased energy consumption are also ignored.

In short, the cost estimates in the draft GEIS are not sufficiently accurate or complete for use in any meaningful cost benefit analysis. The draft GEIS should be redrafted to include accurate and complete data that will reflect the actual economic, environmental, and social costs that will result from the proposed licensing requirements suggested in the draft GEIS.

C. Absence of Rigorous Cost Effectiveness Analyses as the Mechanism for Selecting Proposed Licensing Criteria

All regulatory actions should be premised on rigorous cost effectiveness analyses so that governmental decisions regarding the appropriate use of our nation's resources (including our financial resources) can be meaningfully scrutinized by the public and its elected and appointed representatives. Such analyses must be done on an incremental basis so that incremental benefits can be compared to incremental costs for each level of control. Only with such information can a rational judgment be made concerning the reasonable control levels. This approach is inherent in the Atomic Energy Act, the Mining and Minerals Policy Act of 1970, and the National Environmental Policy Act.

A major defect of the draft GEIS is that such an incremental cost effectiveness analysis is not included in the draft GEIS for the proposed regulatory actions. Perhaps the best example where such an analysis is essential involves radon flux from tailings disposal sites. In Part III of our comments, we have undertaken a detailed cost effectiveness analysis of this proposed criterion. See, Part III, Item A.5. This discussion is summarized below.

The draft GEIS states that the staff rejected the idea of making a fully quantified balancing of costs and benefits in recommending proposed radon attenuation limits. The document states (pp. 12-16 and 12-17):

> The staff chose not to invoke such rigorous cost-benefit balancing because, while it appears to offer a "rational" approach to standard setting

> and avoid arbitrariness, it is inevitable that arbitrary judgments and assumptions must still be made. This is particularly true in the case of radon from tailings because of the uncertainties associated with the very long-term nature of the hazard. Furthermore, such a cost benefit approach would constitute an oversimplification of the tailings disposal problem, which involves many interrelated aspects, and as such would be misleading.
>
> *****
>
> Finally, there is the intractable problem of deciding how much averting a health effect ("life" or "Life shortening" in the case of a premature cancer death) is worth in monetary terms, that is, of deciding what the cost-benefit decision criteria should be. It would be difficult to decide the worth of health effects today and more difficult to decide the value of future effects (that is, 1000, 100,000 years and beyond). Does a premature loss of life 100,000 years into the future have the same value as a life today? Although there has been continuing discussion in public and professional forums concerning the desirability of rigorous cost-benefit procedures, there have been no answers or common acceptance of resolutions to these underlying questions and uncertainties to allow invoking such rigor particularly with regards to long-term hazards.
>
> In view of this, *the staff has weighed alternative radon control levels in terms of how they would meet the simple objective of returning disposal sites to conditions which are reasonably near those of the surrounding environment*.

There is no disagreement that the task is difficult, but to avoid it fails to make use of a substantial body of information which is available and which can provide a valuable frame of reference for decisionmaking. Certainly when such information is available to ignore it would be at least arbitrary and capricious if not wholly irresponsible.

The NRC approach appears more arbitrary when the actual guiding principle for the tailings cover requirement is identified. As stated above in the emphasized quotation from the draft GEIS and in the proposed regulations (44 Fed. Reg.

50017), the guiding principle in developing the proposed tailings cover criterion is to return the site "to conditions reasonably near those of the surrounding environment." To premise the criterion on this principle while at the same time proclaiming a primary objective of the draft GEIS to be a scientific determination of what, if any, regulatory actions are needed, is improper.

It is also improper to dispense with the necessary cost effectiveness analysis with the cavalier statement that the costs associated with satisfying the proposed new licensing criteria will only be 1% of the cost of uranium yellowcake. Ultimately these added costs will fall on present and future U.S. energy consumers. Many millions of dollars more will be spent to meet our energy needs. Each increment of consumer cost must be justified by an appropriate increment of beneficial risk reduction because the public has the right to assure itself that its money is being spent in a prudent and effective manner.

Instead of arbitrarily imposing inflexible, preselected criteria, NRC should examine in the draft GEIS the reasonableness of various levels of radon flux control in relation to the incremental health benefits and incremental costs of these control levels. This needs to be a two part analysis. First, the health risks at the various control levels should be put in perspective relative to other risks present in our daily lives. Second, a rigorous cost effectiveness analysis of the various control levels should be conducted.

Radiological Risk:

While the risks presented in the draft GEIS are greatly overstated as a result of constantly compounding conservative assumptions, in this discussion of relative risk and cost effectiveness, we have used the draft GEIS risk figures. Use of more realistic, lower risk figures simply underscores more forcefully the need to examine relative risks and apply a meaningful cost effectiveness analysis in the process of developing proposed regulations.

The draft GEIS risk factors for the exposure of various groups to radon flux at the rate of 450 pCi/m^2sec from the base case can be translated into the following expected adverse health effects:

Affected Group	Risk (premature deaths/10^5 person-year)(a)
U.S. population	0.00187 (all mills) (b) 2.1 natural background (c)
Regional population	0.0255 (one mill) (d) 0.275 (mill cluster) (e)
Maximally exposed individual	3.15 (one mill) (f) 4.75 (mill cluster) (g)

(a) For consistency purposes, risks will be expressed in terms of "premature deaths/10^5 person-year" as has been done in most instances in the draft GEIS.
(b) Table 6.39, p. 6-72, p. 6-69 (U.S. population equals 88% of continental population and U.S. population at 460 million), draft GEIS.
(c) Table 6.39, p. 6-77, draft GEIS.
(d) Page 6-50, draft GEIS.
(e) Page 6-64, draft GEIS.
(f) Page 6-50, draft GEIS.
(g) Page 6-64, draft GEIS.

Risks in Perscpective -- To put these figures in perspective, the draft GEIS should compare these risks to other daily life risks to the general population. The only daily life risk presented in the draft GEIS is that caused by natural background radiation. A much wider ranging comparison is necessary to gain the proper perspective prior to making a cost effectiveness analysis of alternative regulatory strategies. This is presented in detail in Part III of our comments (See, Part III, Item A.5.). Some of these figures are highlighted below. The risk factors from the draft GEIS for the base case (no controls) are incorporated and underlined at the appropriate points.

DAILY SOCIETAL RISKS AND NONOCCUPATIONAL RISKS FROM URANIUM MILLING

Activity	Risk/Year (deaths/10^5 person-year) (2)
Smoking, all effects (including heart disease)	300
Smoking, cancer only	120
Motor vehicles	22
Alcohol, heavy drinker (cirrhosis of the liver)	16
Falls	7.7
Cancer from alcohol drinking (smokers and nonsmokers)	5
Living for one year downstream from a dam (calculated)	5
Maximally exposed individual for cluster of 12 model uranium mills	4.75
Pedestrian, auto accidents	4
Football	4
Maximally exposed individual for one model mill	3.15
Skiing	3

Table III Cont.

Natural background radiation	
Living in Denver	2.5
U.S. Average	2.1
Regular use of oral contraceptives	2
Drowning	1.9
Natural background radiation at sea level	1.5
Radiation induced cancer in frequent airline passengers	1.5
Home Accidents	1.2
Cancer from drinking one pint of milk/day (aflatoxin) or drinking one diet soda per day (saccharin)	1
Person in room with smoker	1
Tornadoes (average over many years)	0.5
Hurricanes or lightning	0.3
Smallpox vaccination	0.3
One transcontinental airplane trip/year (noncancer)	0.3
Regional population exposure for cluster of 12 model uranium mills	0.275
Drinking water of Miami or New Orleans	1.12
Cancer from eating one charcoal broiled steak per week (heart attack, choking, etc., not included)	0.04
Regional population exposure for one model uranium mill	0.025
U. S. population exposure for all model uranium mills projected by draft GEIS	0.00187

When placed in this context, it is evident that the risks attributed to uranium mill tailings radon flux are at the lowest levels of the risks that the general population deals with every day. For the regional population, the average individual is 80 times more likely to die from a motor vehicle accident than he is from cancer induced by a cluster of 12 model uranium mills in the region where he lives. For a single model mill this factor becomes well over 800 instead of 80. The average U. S. citizen is over 600 times more likely to die from an accident in his home than he is from cancer induced by radiation from all the uranium mills projected by the draft GEIS.

Further perspective on these radiation risks from uranium mill tailings has been provided by work by Dr. Bernard Cohen, a noted nuclear physicist at the University of Pittsburgh. Using the draft GEIS risk figures Dr. Cohen prepared a report for AMC (See, Part III, Item A.4.) translating these figures into equivalent terms for various daily life activities. Dr. Cohen calculated that radioactive emissions from all the projected model mills would reduce the life expectancy of the average U. S. resident by 15 minutes. Other activities that also cause this same 15 minute loss are 1) smoking 1 1/2 cigarettes in a lifetime, 2) an overweight person eating 100 extra calories (e.g. one soft drink or one piece of buttered bread) in a lifetime, 3) driving an extra half mile per year, 4) crossing a street one extra time very two years, 5) taking one short airplane flight in a lifetime, 6) living in a house without a smoke detector for one month of one's life, or 7) living downstream from a dam for one week.

<u>Risks at various radon control levels</u> -- Risk factors and incremental health effects can be readily calculated for

various radon flux rates and populations using the BEIR II nonlinear threshold and UDAD Code assumptions employed in the draft GEIS.* Our detailed calculations (See, Part III, Item A.5.) are summarized below for the continental population case.

Radon Flux Rate (p Ci/ m^2sec)	Health Effects per Year		Risk (deaths/10^5 person year)
	Cumulative	Incremental	
450	9.70	-	0.0021
100	2.13	7.57	0.00046
50	1.07	1.06	0.00023
10	0.213	0.86	0.000046
5	0.117	0.106	0.000023
2	0.042	0.075	0.000009

Cost Effectiveness Analysis of Various Radon Flux Control Levels:

Before undertaking a cost effectiveness analysis, four elements are necessary. First, of course, are the risk factors presented above for various radon flux levels. Second is the cost of achieving these various flux levels. Third is the period over which the health effects averted per year are to be integrated. Fourth is the "yardstick" from which to make a decision as to the appropriate societal cost per adverse health effect averted. This "yardstick" is discussed below followed by costs for various control levels and the appropriate integration period. These elements are finally brought together in a cost effectiveness analysis for these various radon flux rates.

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* While we seriously question both the BEIR II and UDAD Code analyses, for this analysis we will assume their accuracy.

Range of Cost-per-Health Effect-Averted Figures -- Society consistently attaches dollar values to health effects. In Part III, Items A.4 and A.5, we have compiled figures from several sources including both actual expenditures and values suggested by other regulatory programs. The high end of these figures was about \$4 million per health effect averted and the low end was roughly \$6,000. From the full range we believe the appropriate yardstick is in the \$250,000 to \$500,000 range.

Costs for Proposed Tailings Cover Requirements as Presented in the Draft GEIS -- The draft GEIS presents cost figures for covering the model 100 ha (250 acre) tailings disposal area under the various alternatives for various types of soil. When presenting these figures in Chapter 11, the draft GEIS uses a cost of $\$1.30/m^3$ ($\$1.00/yd^3$) for moving the cover material onto the tailings area and compacting it in place. We have discussed elsewhere in these general comments the underestimation of true costs of various earthwork procedures.*/

The present discussion will be restricted to the draft GEIS cost per cubic meter (cubic yard) figure for covering the tailings.

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*/ A more realistic cost figure would be \$3.90/m3 or $\$3.00/yd^3$. Further, the assumption that the cover soil will be "essentially 'free' (Draft Geis, section 11.3.2, p. 11-9) is wholly unjustified. Not only is it certain that the owner of suitable cover soil (whether a private citizen or a government) would undoubtedly charge for the material, there would also most certainly be additional costs involved in properly reclaiming the site from which the soil is taken. See, discussion of costs.

Using the equation presented in the draft GEIS for calculating the thickness of cover materials necessary to reach a particular radon flux level at the surface of the cover material[*] and the material characteristics constants for the various typical soils examined in the draft GEIS,[**] we have calculated cover depth requirements for various radon flux rates from 450 pCi/m^2sec (draft GEIS "base case" situation) to 2 pCi/m^2sec. Using the $\$1.30/m^3$ ($\$1.00/yd^3$) cost from the draft GEIS, we have calculated cost figures for these cover depths for this same range of radon flux rates and the different soil types. We have also calculated the incremental cost of adding each additional amount of cover to move from one flux rate to the next lower flux rate. These calculations are presented in tabular and graphic form in Part III of our comments.

Period of Integration of Health Effects -- The draft GEIS notes that by using a long enough integration period "almost any amount of money for control of radon could be 'justified'." Draft GEIS, p. 12-17. This does not, however, justify the failure of the draft GEIS to choose a rational integration period and to perform a cost effectiveness analysis.

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[*] Equation (1), p. 9-24 and equation (1), App. P, p. P-1, draft GEIS.

[**] This constant, D/P, is presented for soils A, B, & C and clay in figure 9.1, p. 9-25 in the draft GEIS.

A reasonable integration period should be selected. Many considerations will affect this selection. Over extremely long time periods erosion will bring essentially all the naturally-occurring radioactive materials close enough to the earth's surface to permit radon emanation. If we integrate over very long (geologic) periods, there is no net harm in mining uranium and creating mill tailings; the total number of health effects will be the same. Therefore, an extremely long integration period is useless.

Further, we recognize that predicting events over tens of thousands of years is unreasonable. Particularly when dealing with health effects which will be at the lowest end of daily life risks, it is not appropriate to make such predictions. Projections should be confined to a time period for which we can make even the most generalized prediction -- time periods of no more than a few hundred years. This is equally true as to any moral obligation to future generations. To adopt the philosophy that we should maintain our resources in an unchanged condition for future generations would deprive those generatgions of the many benefits of technological innovations. Our goal should be to provide our progeny a world in a better overall condition.

We have used a 100-year integration period in our analysis based on consideration of these factors.

Cost Effectiveness Analysis -- Combining the incremental costs with the incremental health effects averted for a 100 year integration yields the following graphic presentation for incremental cost per health effect averted for the various soils examined in the draft GEIS. See, Figure 1. The $250,000 to $500,000 "yardstick" is superimposed on the graph. A more detailed analysis is presented in Part III, Item A.5.

From this analysis it is immediately evident that the appropriate radon flux level is strongly dependent on the type of cover material used. At the acceptable cost level, a flux rate of 60-100 pCi/m^{2}sec can be reached with soil B at a cover depth of 2-3 meters. For soil A, the flux range is 40-60 pCi/m^{2}sec with a depth of 1-1/2 to 2 meters. If the clay plus soil A option is available, a flux rate of 4-7 pCi/m^{2}sec can be achieved with about 1-1/4 meters of material.

These calculations have all been based on the figures in the draft GEIS. We have discussed elsewhere the errors involved in these draft GEIS numbers. In Part III, Item A.5, we have done a cost effectiveness analysis using figures which we consider to be closer to reality. See, Figure 2. Suffice it to say for purposes of the present discussion that each of the curves for the various soil types shifts upward. Therefore, the radon flux rate that falls within the acceptable incremental cost per health effect averted range is higher than that calculated from the draft GEIS figures.

From this analysis, two points are readily apparent. First, there is no justification for an inflexible requirement for a minimum of three meters of cover material in every case. On a cost effective basis, the appropriate radon flux rate and the corresponding cover depth, is critically

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GEIS ESTIMATE OF INCREMENTAL COSTS PER INCREMENTAL HEALTH EFFECT AVERTED

Continental Effects

100 Year Integration

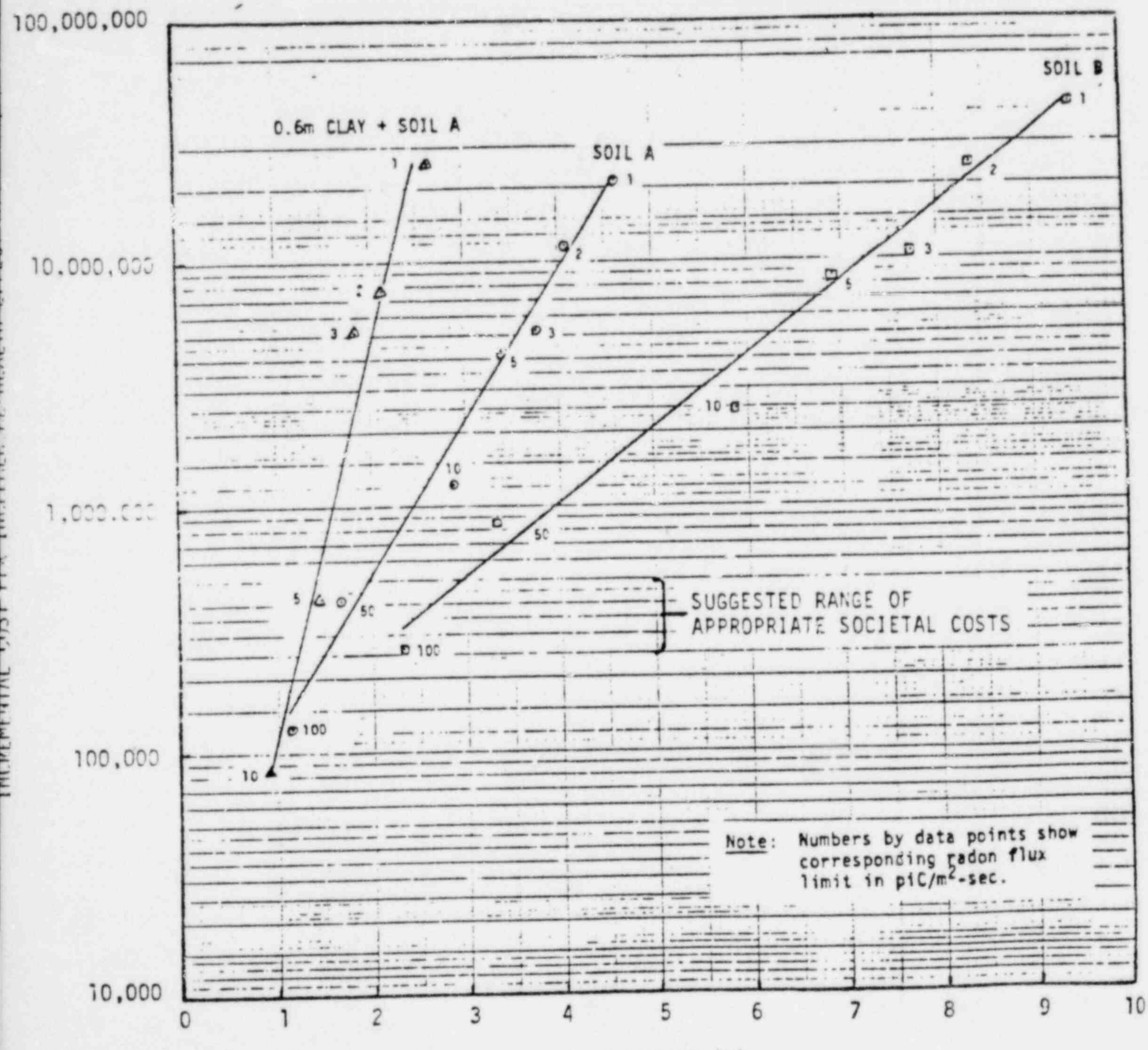
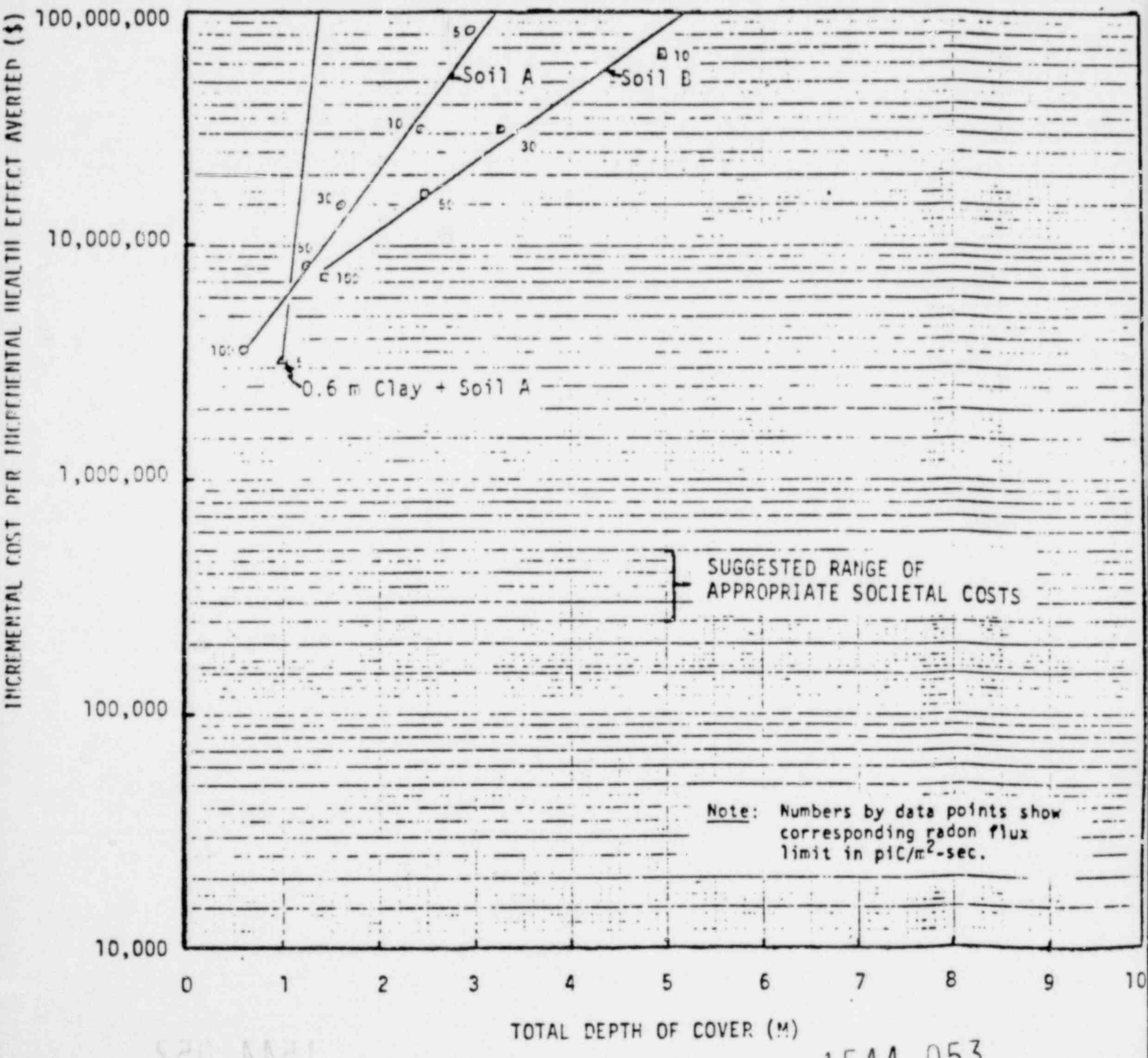


FIGURE 2

AMC ESTIMATE OF INCREMENTAL

COST PER INCREMENTAL HEALTH EFFECT AVERTED

Continental Effects 100 Year Integration



Note: Numbers by data points show corresponding radon flux limit in piC/m^2-sec.

dependent on the type of cover material used. This criterion should be rewritten to recognize this needed flexibility.

The second conclusion from this analysis is that a radon flux rate of 2 pCi/m^2sec is not justifiable on a cost effectiveness basis for <u>any</u> type of cover material. To reach 2 pCi/m^2sec, costs would range from $8 million to $24 million per health effect averted for the three cover materials of soil B, soil A, and soil A plus 0.6 meters of clay. The cover depths would be 8, 4, and 2 meters respectively. Even with a one thousand year integration, the cost per health effect averted would range from $2.4 million to $800,000. When cost and risk figures more accurate than the draft GEIS figures are used, the cost of achieving a 2 pCi/m^2sec above background emanation rate is off the graph, exceeding $100 million for all types of cover material.

As to tailings cover requirements, our conclusion is that large expenditures of societal resources to reduce radon flux from tailings piles to very low levels is neither cost effective nor reasonable. There are many more effective ways to reduce societal risks. The inflexible level of 2 pCi/m^2sec specified in the proposed licensing criteria is unreasonable. Site specific considerations, such as the cover material available at a reasonable cost, must strongly influence the acceptable radon flux rate.

This also demonstrates that realistic cost effectiveness analysis of the proposed licensing criteria is indeed possible. The draft GEIS should be redrafted to incorporate such a cost effectiveness analysis of the proposed criteria so that the

Commission, with appropriate public input, can make a rational decision on what, if any, licensing criteria are necessary and what control levels those criteria should establish.

LACK OF FLEXIBILITY

One of the purposes of the draft GEIS is to develop and publish for public discussion the information necessary to amend regulations for the licensing of uranium mills in the United States. The regulations should be designed to protect health and minimize danger to life and property without impeding U.S. uranium production.

NRC should establish, from scientific data, performance standards rather than rigid design requirements. Such standards could set exposure limits to be met by every operation, while allowing each company to meet these standards using the methods that are most suitable in each site specific situation. The scientific data on which such standards must be based is the critical factor in establishing any regulations. This approach allows flexibility in meeting the standards and should be used by NRC in regulating uranium milling.

Since uranium mills do have significant operational differences it is important that any licensing regulations take into account the site specific variations. The industry feels strongly that any licensing standards or regulations should (1) assure the adequate protection of health and (2) allow each operator to meet the standards using the methods and materials that are most appropriate and cost effective for the particular situation. It is important that the regulatory requirements be flexible.

Uranium milling operations in the United States may have some generic similarities, but processing and disposal factors vary considerably from site to site. Some of the variables include the composition of the ore body, the size of the ore body, the nature of the native soil, the amount of available land to build a mill or to dispose of tailings, the proximity of the available land to the ore body, the topography, the location of the nearest population centers or anticipated population centers, meteorological conditions, groundwater conditions, surface water conditions, ownership of land (Federal, State, Indian, private), and available or anticipated transportation routes. Each of these and other factors determines the specifics as to how a mill actually operates. Actual production can and does vary considerably even between mills that are in close proximity to each other.

The approach taken in the draft GEIS and in the proposed regulations is not correct. There is no explanation of what the proposed regulations are designed to achieve and there is no discussion of the relationship between alternative disposal methods and population exposures. The draft GEIS (Chapter 12) explains what requirements may be imposed, but does not explain why the requirements are necessary. It is essential that in the next draft of the GEIS contain information explaining the basis and purpose of the regulations. The omission of this data in the current draft is a critical error.

The approach taken in the draft GEIS and the proposed regulations has another basic deficiency. Although the draft GEIS continuously stresses the importance of flexibility and the need to consider site-specific factors, the proposed licensing criteria are quite rigid. The proposed regulations contain positive and specific statements as to what requirements should be imposed. For example, the proposed regulations require a minimum of three meters of earth cover to be placed over tailings piles in order to reduce radon to less than 2 pCi/m^2sec above natural background levels. Other emanation rates and cover depths are not scientifically evaluated nor is any scientific jusitification presented for the proposed emanation rate and cover depth.

The proposal also defines below grade tailings disposal as the "prime option", but notes that above grade disposal can be used if it is "demonstrated" that the disposal program will provide adequate isolation of the tailings. The "prime option" should be <u>the adequate disposal of tailings</u> either above or below grade. To list one method as a "prime option" establishes a presumption in favor of one method and thus disregards the importance of site-specific considerations. If several methods can be used to comply fully with the standards, none should be singled out as the "prime option".

Another example of the inflexibility of the proposed requirements is the provision that requires maximum reduction of seepage into groundwater. Again this establishes a definite presumption in favor of reducing seepage when in some cases there may be little or no benefit derived. The goal of the criterion should be to protect groundwater rather then just to prevent seepage. As described in more detail below (See Part III, Item B), it is better to study the individual site's hydrology, geology and subsoil, and using that data select the tailings management system that most adequately protects the groundwater.

Another example of the lack of flexibility is also illustrated in the decommissioning criteria proposed in the draft GEIS. These consist of very stringent "target" criteria and somewhat less stringent "upper limit" criteria. The actual criteria should be developed on a site-specific basis setting levels as low as reasonably achievable, but somewhere between the upper limit and target criteria.

The target criteria proposed in the draft GEIS are far too stringent. At the levels proposed it will be difficult if not impossible to distinguish between the levels required by the criteria and normal variations in background. [See Part III, Item D).

Flexibility is also needed in the proposed financial surety arrangements. Only a limited number of financial arrangements are acceptable to the NRC. There are a number of additional arrangements that should be acceptable, e.g., self-insurance or third party (i.e., federal, state, local, or private entity) responsibility [See Part III, Item E]. Also, it should be made clear that NRC will not duplicate requirements where states already have applicable bonding programs.

The proposed criteria are inappropriate as there is no scientific basis for them. Those familiar with NRC mill licensing, of course, immediately recognize them as various regulatory guides, branch position papers, and performance objectives issued by NRC over the last several years. (See

Part III, Item G). The industry seriously questions the legitimacy of these items. They will most assuredly become unofficial "absolutes" in the issuance of mill licenses, both by NRC and by Agreement states. In the evolution of the permitting process, the NRC policy positions will become the minimum requirements for all licenses. Site-specific consideration will disappear and any semblance of cost-effective management techniques will be lost.

Once the criteria have been used in a few licenses, the NRC and the Agreement states may be forced to defend themselves in litigation or in agency proceedings for not strictly adhering to the criteria in all cases.

The proposed criteria will stifle the development of new mining technology which could reduce adverse environmental impacts. An example of this is borehole mining designed to recover pockets of uranium ore which otherwise would be uneconomical to mine. It involves the discharge of water from a high pressure jet into the ore body to form a cavern 30 to 40 feet in radius. The procedure significantly reduces environmental impacts such as surface disturbance and dust emissions. Proposed criteria 1 however, "recommends" that wastes from small remote extraction operations be disposed of at existing large mill tailings sites. This could preclude extraction of the uranium by borehole mining because the cost to haul the tailings to an existing mill, rather then dispose of them underground at the site, would in most situations be prohibitive.

If the uranium industry in this country is forced to use a limited number of defined disposal techniques, production may be impossible in some situations. Also, costs may be needlessly increased and there will be no incentive to develop and use new, improved mining and disposal techniques.

When the GEIS is redrafted, it should specifically define the public health goals which NRC plans to achieve, and explain how these goals were developed. Operators may then select the most cost effective methods of meeting these goals, taking into consideration site-specific conditions. The flexibility provided in achieving performance standards will protect public health, maximize U. S. production of uranium, minimize production costs and encourage new and improved mining and disposal technology.

THE PREMATURE AND POTENTIALLY CONFLICTING NATURE OF THE PROPOSED REGULATIONS

NRC is acting prematurely in proposing regulations at this time to cover the various areas identified in the draft GEIS. If promulgated in the near future, these proposed regulations will require the uranium milling industry to make major plans and commitments to meet one set of standards now, only to have the standards changed in response to anticipated Environmental Protection Agency (EPA) standards.

NRC should recognize that Section 275 of the Atomic Energy Act, 42 U.S.C. 2022, requires EPA to promulgate standards covering uranium mill tailings by May, 1980. The standards are to have general application for the protection of public health, safety and the environment from radiological and non-radiological hazards associated with processing, possession, transfer and disposal of mill tailings. The Act contemplates that standards first be developed by EPA and then, rules be promulgated by NRC, rather than the order of events currently being proposed. Because of the statutory requirement of public participation in the development of EPA's standards, neither NRC, EPA nor anyone else can presently anticipate EPA's final standards. In this regard, it should also be noted that the published listing of information EPA intends to rely on in developing the standards is by no means limited to the information contained in the draft GEIS. (See 44 Fed. Reg. 33433).

The promulgation of regulations by NRC prior to publication of EPA's standards may force the uranium milling industry to make expenditures necessary to meet the NRC requirements and then repeat the process to comply with those established by EPA. These unnecessary expenditures would be inflationary. It is hoped that, before the NRC decides to promulgate regulations on its present timetable, it will first consider the requirements of Executive Order 12044.

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PART III

SPECIFIC COMMENTS BY THE AMERICAN MINING CONGRESS ON THE DRAFT GENERIC ENVIRONMENTAL IMPACT STATEMENT (GEIS) ON URANIUM MILLING (NUREG - 0511) AND ON THE PROPOSED REGULATIONS ON CRITERIA RELATING TO URANIUM MILL TAILINGS AND CONSTRUCTION OF MAJOR PLANTS (44 FED. REG. 50015, et seq.)

FOUNDED 1897

Submitted on October 24, 1979

AMERICAN MINING CONGRESS

Founded in 1897, the American Mining Congress is an industry association that encompasses (1) producers of most of America's metals, coal, industrial and agricultural minerals; (2) manufacturers of mining and mineral processing machinery, equipment and supplies; and (3) engineering and consulting firms and financial institutions that serve the mining industry.

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J. Allen Overton Jr.

J. Allen Overton, Jr.
President

VOLUME I

PART III

SPECIFIC COMMENTS BY THE AMERICAN MINING CONGRESS ON THE DRAFT GENERIC ENVIRONMENTAL IMPACT STATEMENT (GEIS) ON URANIUM MILLING (NUREG-0511)

AND ON THE PROPOSED REGULATIONS ON CRITERIA RELATING TO URANIUM MILL TAILINGS AND CONSTRUCTION OF MAJOR PLANTS

(44 FED. REG. 50015, et seq.)

Prepared by the AMC Uranium Environmental Subcommittee

Submitted on October 24, 1979

Part III
SPECIFIC COMMENTS

VOLUME I

Part III

A. Radiological Aspects

1. Overestimation of Risks

1

COMMENTS ON RADIOLOGICAL IMPACT SECTION

(Chapter 6, pages 6-20 to 6-80, Vol. I.)

OF DRAFT GENERIC ENVIRONMENTAL IMPACT STATEMENT (GEIS)

ON URANIUM MILLING

The myriad calculations made in estimating the radiological impact of uranium milling in the GEIS are completely dependent on many of the assumptions made for the "model mill" which is described in Chapter 5, along with the dozens of assumed parameters and characteristics attributed to this "model mill."

Many real uranium mills actually exist. A "model mill" is a creature of the imagination, designed for the convenience of the people preparing environmental impact statements. It reminds one of the story of the man who tried to wade across a river he had been told had an average depth of three feet. He drowned in midstream where the depth was eight feet.

In addition to the many assumptions in Chapter 5, additional assumptions as to radiological factors, sources of radioactivity, exposure pathways, locations of dose receptors, etc. are set forth in Chapter 6, and in Appendix G-1. These assumptions as well as those set forth in Chapter 5 do not necessarily represent _any_ single uranium mill. The radiological impacts calculated for the "model mill" do not, therefore, represent the radiological impacts from _any_ single, real uranium mill. This being the case, the usefulness of this part of the GEIS and of the expenditure that went into producing it are questionable. There may be a limited usefulness in that the results, especially the health impacts, can be looked at as the upper limits of risk from uranium mills due to the "conservative" (i.e., biased towards producing a worst case result) assumptions used.

Many of the assumptions used are buried in the text of Chapter 6 and one must read each and every paragraph assiduously to find these assumptions. Some assumptions are made but are not described in the text or the appendices. They are inherent in the methods of calculation used or in the data taken from reference sources. These assumptions should be listed in the GEIS or in its appendices.

The conclusions reached with regard to meeting NRC and EPA limits are true only for the imaginary "model mill." To determine whether or not any real uranium mill can meet these limits requires that the calculations be done over again using data applicable to the mill in question, unless one can show that none of the data for a particular mill are less "conservative" than the assumptions for the "model mill." In such a situation, the health risks could not be higher than those predicted for the "model mill" in the GEIS.

The exercise of calculating radiological impacts to continental populations as far distant as northern Mexico and southern Canada seems to add little meaningful data in view of the negligible effects involved.

Some of the following specific assumptions are questionable and bear discussion:

1. Section 6.2.8.2.3, Location of Dose Receptors, page 6-23, subparagraph (a).

The assumption is made that the point of maximum air concentrations which is accessible to the public is the fence location in the downwind direction and that this is 100 meters from the edge of the tailings area, 0.64 Km. east-northeast of both the mill and center of the tailings pond. Maximum occupancy of this location is assumed to be 10% of the year.

The 10% occupancy figure assumed seems very high. The only normal occupancy of the assumed area of maximum air concentrations is people passing by the tailings pile and mill. Most real uranium mills have no other type of occupancy this close to a real tailings pond or pile. The 10% assumption means that an affected person is expected to spend 2.4 hours per day, 365 days per year in this location. The members of the public passing by are more likely to be in the location a matter of a few minutes per day, and then only on some days. A more reasonable assumption would be much less than 1% of the year.

2. Section 6.2.8.2.3, Location of Dose Receptors, page 6-23, subparagraph (b).

The assumption in sub-paragraph (b) is that the closest downwind location where a temporary residence (mobile home or trailer) might be established is 0.4 Km. from the tailings area and 0.94 Km. from the mill. It is further assumed that vegetables are grown here and that occupancy is only six months per year.

Most real uranium mills are located in arid areas where vegetable gardens are extremely difficult to grow due to lack of water, poor soil, short growing seasons and other adverse environmental conditions. No explanation is given as to why six months occupancy is assumed. The people living in such an area are likely to be employees of or in some way dependent on the uranium mill (or mines). Such people do not normally maintain two living quarters. Perhaps the six months occupancy reflects the authors' assumption that these occupants are basicially itinerants. The statement should give some background data justifying both the vegetable growing and the occupancy assumptions.

3. Section 6.2.8.2.3, Location of Dose Receptors, page 6-23, subparagraph (c) and Section 6.2.8.2.4.3, Internal Exposure via Ingestion, pages 6-27 thru 6-30.

The assumption in subparagraph (c) is that the closest permanent residence downwind of the site is a ranch 2.0 Km. from the mill, occupied year round, where vegetables and beef cattle are grown, and milk cows on the property satisfy household milk requirements.

Again, one must remember that real uranium mills are mostly located in arid regions. The discussion in subparagraph (b) on vegetable growing applies equally well here. Furthermore, in such arid regions, beef cattle and milk cows must range over large areas of land in order to find enough grazing material. The cattle are not necessarily going to spend the entire time at the ranch house exactly 2.0 Km. from the mill. The equation used (Appendix G-3, page G-23, Section 5) to derive concentrations in meat and milk apparently does not take into account the varying distance of grazing cattle from the mill.

The assumption that there are milk cows on the property to satisfy the household milk requirement is a poor one. Due to the aridity of areas where present day real uranium mills are located, it is unusual to have any milk cows in the area. The authors recognize this to some extent with the following statement on pages 6-29:

> "Staff contacts with state agricultural agents in primary milling states have indicated that on the order of twenty percent of local farms and ranches can be expected to have one or more dairy cattle. Thus the milk pathway is considered to be somewhat more hypothetical than the beef or vegetable pathways."

In Figure 6.6 and Tables 6.10 and 6.11, an attempt is made to recognize this milk cow discrepancy by presenting two curves, or sets of data: one for a child with a milk pathway and one for adults without a milk pathway. Unstated assumptions made in these calculations are, (1) that all children drink cows' milk, and, (2) that no adults drink cows' milk. In the real world, many children are breast fed or are allergic to cows' milk and do not, therefore, drink it, and many adults do not drink cows' milk.

The above discussion of vegetable and milk pathways assumptions is also applicable to the calculations of Annual Population Dose Commitments, the results of which are presented in Table 6.15, page 6-39.

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4. Section 6.2.8.2.4.4, Total Individual Dose Commitments, pages 6-31 to 6-35.

This section discusses compliance with EPA's 40 CFR Part 190 regulation. The calculations presented and conclusions drawn are all based on the "model mill," and, therefore, have no validity with respect to a real uranium mill, which might have a lower impact. These calculations must be redone for each real uranium mill using the specific site data for each such mill. Different conclusions may be drawn for each such mill depending on the specific data from each such mill and the results of the calculations. The results of the calculations for the "model mill" and the conclusions drawn from their results cannot and should not be used to determine whether or not a specific real uranium mill or real uranium mills as a group can or cannot meet the EPA regulation.

5. Section 6.2.8.2.4.2, Individual Internal Exposure via Inhalation page 6-27.
Section 6.2.8.2.5, Regional Population Exposure, pages 6-35 to 6-40.
Section 6.2.8.2.6, Health Effects on Man, page 6-41.
Section 6.3.8, Radiological Impact (of multiple mills, pages 6-63 and 6-64.
Section 6.4, Continental Radiological Impacts, pages 6-64 to 6-73.

The term "conservative" is frequently used throughout the document and appendices. It generally is used to indicate that a particular assumption or line of reasoning will yield a predicted health effect or exposure result that is somewhat higher than may be experienced in the real world. Some such "conservatism" can be justified on the grounds that where uncertainty exists in the calculations, it is better to err on the high side in predicting exposures and health effects. There is a danger, however, that "conservative" factors can be pyramided until the result is a gross distortion of what in reality can be expected. This has occurred in the prediction of health effects due to the diffusion of radion from tailings piles, and the subsequent exposure of public populations to radon daughters.

On page G-58, Appendix G-7, "Health Effects from Irradiation," is is stated that the 1972 BEIR report data are used, but modified due to a statement in the NAS 1976 report entitled, "Health Effects of Alpha-Emitting Particles in the Respiratory Tract." The specific modification adopted is stated in the GEIS to be an increase in the absolute risk coefficient for lung mortality from 1.3 to 2.0 mortalities/year/10^6 person-rem. It is further stated in the GEIS that this modification "was based on new data on U.S. uranium miners exposed to radon." When one reviews the 1976 NAS report, the modification is found in Appendix A, page A.66, in a section written by E. P. Radford. The "new data on U.S. uranium miners exposed to radon" is not given but is referenced from unpublished 1975 data of V. E. Archer and E. P. Radford. This data has since been published by Archer & Radford, but only in the form of conclusions. The numerous statistical calculations which had to be performed on the basic data from different sources because these were not available in the same or common terms and the assumptions involved in each of these calculations have not been published nor, therefore, subjected to peer or public review. The NRC staff should await publication of these calculations and assumptions and their review by the scientific community.

The data which entered into the 1972 BEIR report calculation of the absolute risk for the U.S. white underground uranium miners are the following:

Observed deaths	130
Expected deaths	13.9
Excess deaths	116.1
Person years at risk	38,622
Mean dose to tissue-rads	475
REM per rad (RBE)	10

The calculation of absolute risk was as follows:

$$\text{Abs. risk} = \frac{116.1 \text{ excess deaths} \times 10^6}{38{,}622 \text{ person years}} \div \left(\frac{475 \text{ rad}}{\text{person}} \times 10 \frac{\text{rem}}{\text{rad}}\right) \qquad (1)$$

$$= 0.63 \text{ deaths}/10^6 \text{years}/\text{rem}$$

Footnote b to Table f-1 on page 151 of the 1972 BEIR report states that the data used were updated to 1971 by having Dr. Victor E. Archer add new lung cancer cases. Dr. Archer did not, however, update the person years at risk or the expected deaths. No systematic follow-up was done to determine the person years at risk as of that time. The expected deaths were estimated by Dr. Radford using a shortcut method rather than the modified life table calculation used in the uranium miners study. (Verbal communication from Dr. Archer.)

The figure of 0.63 derived as shown above, was averaged with 1.61 fo the Fluorspar Miners, 1.2 for Spondylitis Patients, and 0.60 for Hiroshima and Nagasaki survivors resulting in the average absolute risk of 1.0 deaths/10^6 years/rem as cited above.

The NRC staff have apparently misunderstood the 1976 NAS revision of absolute risk. For clarity, the pertinent portion of this report is quoted below (Underlining ours):

> "Finally, it has been possible to update the U.S. uranium miners study group to 1972. As expected, the cancer incidence rate has remained high, at roughly 30 times the rate in the remainder of the U.S. population. Adding the new lung cancer cases modifying the definition of

> period at risk from 5 years after beginning of mining (used in the Interagency and BEIR reports) to 10 years after beginning of mining, and eliminating three cases which occurred during the 5-10 year period (which is probably less time than the latent period for lung cancer) results in a revised absolute risk of about 2 cases/rem/10^6 person years."

We read this language to mean that the absolute risk factor of 0.63 for the U.S. white underground uranium miners, as worked out above and in the BEIR report, is revised to 2. The NRC staff has apparently interpreted it to mean that the BEIR report absolute risk factor of 1.0, arrived at after averaging the U. S. white uranium miners study group result with those of the Newfoundland Fluorspar Miners, the Spondylitis patients, and the Hiroshima and Nagasaki survivors, has been raised to 2. No mention is made in the 1976 NAS report of any revision of the three groups other than the U.S. uranium miners group, so that the 1972 BEIR report values for those groups are still to be used. If we substitute the revised U.S. uranium miners absolute risk figure of 2 for the previous figure of 0.63 to determine the revised average of the four groups, this revised average absolute risk figure works out to 1.3 instead of the 2 used by the NRC staff in the GEIS.

Furthermore, the figure of 2 for the U.S. uranium miners is subject to some question. Neither the person years at risk to 1972 nor the observed and expected cases to 1972 in the U.S. uranium miners group were provided in the 1976 NAS report. No systematic follow up of the group and no modified life table calculations of the expected cases were made at that time. Follow up was done and modified life table calculations were made, however, as of the end of September 1974 and reported in "Respiratory Disease Mortality Among Uranium Miners" by Victor E. Archer, J. Dean Gillam, and Joseph K. Wagoner, published in Annals of New York Academy of Sciences, Vol. 271, "Occupational Carcinogenesis," 1976. From this the following data are available for substitution in equation (1) above:

Observed deaths	144
Expected deaths	29.8
Excess deaths	114.2
Person years at risk	46,111
Mean dose to tissue-rads	475 (See text below)
Rem per rad (RBE)	10 (See text below)

The mean dose to tissue and RBE were not given in the September 1974 study, so for the following calculations are assumed to be the same as used in the 1972 BEIR report. The mean dose to tissue could only have increased since 1971, which would tend to lower the absolute risk in the following calculation even further.

(Note that the 1974 data, derived from detailed follow up and the use of the modified life table calculations gives less excess deaths in the group as of September 1974 than E. P. Radford got in 1971 for the BEIR report with his shortcut method.)

Using the above data in equation (1) the absolute risk works out as follows:

$$\text{Abs. risk} = \frac{114.2 \text{ excess deaths} \times 10^6}{46{,}111 \text{ person years}} \div \left(\frac{475 \text{ rad}}{\text{person}} \times 10^6 \, \frac{\text{rem}}{\text{rad}}\right) \quad (2$$

$$= 0.52 \text{ deaths}/10^6 \text{person years/rem}$$

If we substitute the 2 and 1.3 absolute risk coefficients discussed above into equation (1) and use the other 1974 data and solve the equation for excess deaths we get 438 and 284 respectively - far in excess of the actual 114.2. If we use the 1972 BEIR report numbers of 0.63 and 1 we get 138 and 219, respectively, which are also in excess of the actual 114.2. The absolute risk numbers of 0.63, 1, 1.3, and 2 are all, therefore, too high for the U.S. uranium miners study group.

If we average the above calculated absolute risk of 0.52 for the U.S. uranium miners group with the other 3 groups as was done in the 1972 BEIR report, we get a figure of 0.98 compared with the 2 used in the GEIS. Thus a bias of 100% towards overstating the health effects has been introduced into the GEIS.

If the NRC staff is correct in its interpretation that the 1976 NAS revision of the absolute risk coefficient to 2 was a revision of the 1972 BEIR report absolute risk coefficient of 1 after averaging the U.S. white underground uranium miners figure with the other 3 study group figures, then it can be calculated that the U.S. white underground uranium miners figure must have been revised from 0.63 to 4.59 since the revision "was based on new data on U.S. uranium miners exposed to radon" and not to revision of the numbers for the other 3 groups. If we use this 4.59 figure for the U.S. uranium miners in equation (1) along with the 1974 data given above and solve for the excess deaths, the answer comes out 1005 compared to the actual 114.2 excess deaths in the group at that time. Obviously this interpretation of the 1976 NAS revision statement is incorrect.

Another item that casts doubt on the use of the 1972 BEIR report numbers for the U.S. uranium miners study is the relative risk (observed deaths divided by expected deaths in the study group). When this is computed from data obtained by detailed follow up of the group and from modified life table calculations, the relative risk is much lower than the 9.4 given in the BEIR report. Such relative risk numbers were calculated recently by Joseph K. Wagoner and presented in his testimony to the Subcommittee on Health & Scientific Research of the U. S. Senate Human Resources Committee and the Senate Judiciary Committee on June 19, 1979. The following table is taken from his testimony:

Table 1

Respiratory Cancer Mortality Among White Underground Uranium Miners

Period of follow up	Obs.	Exp.	Relative Risk	Attributable Risk
1950 - Dec. 1962	12	2.8	4.29	9.2
1950 - Dec. 1963	22	5.7	3.86	16.3
1950 - June 1965	37	7.4	5.00	29.6
1950 - Sept. 1967	62	10.0	6.20	52.0
1950 - Sept. 1968	70	11.7	5.98	58.3
1950 - Sept. 1974	144	29.8	4.83	114.2

Note the decline in relative risk from the peak of 6.2 in 1967 to 4.83 in 1974. At no time did it approach the 9.4 derived for 1971 in the 1972 BEIR report.

Giving equal weight to the U.S. uranium miners study and to the fluorspar study as is done in the averaging done in the BEIR report also seems to be an improper procedure. The uranium miner study is of 3,366 white U.S. males who were carefully interviewed at the time of their enrollment in the study by the U.S.P.H.S. These interviews collected occupational and smoking histories of each individual in the study group. In addition, a thorough follow-up procedure was used. Thus very good data exist on this group, especially with regard to smoking histories. The exposure data on many of these individuals was accumulated based on measurements of WL's in most mines at the time most of these individuals worked in them. Some estimates had to be made of exposure before some of the men became part of the study group, as about half the men in the group had worked one to ten years in uranium mines before being enrolled in the group. The smoking histories showed that the group smoked much more than the average for U.S. white males and was sufficient to account for about a 49% excess over the expected lung cancer cases in the group.

The fluorspar miner study involves only about eight hundred miners. Furthermore, these miners were not interviewed at the time they were working in the fluorspar mines. Smoking histories were available on a sample, but not on all miners, and indicated they smoked even more than the U.S. miners, but no correction factor for this was ever calculated. Exposures to radon daughters were all estimated from WL's measured after the high lung cancer mortality among these workers was recognized. By that time a number of the mines had been closed due to flooding. The exposure estimates were made by measuring WL's in mines that had adopted mechanical ventilation and estimating what the levels would have been without such mechanical ventilation in years prior to their measurement.

The equal weight given to the results of these two studies in the 1972 BEIR report is highly improper. One study had 3,366 workers, the other 800. The first study had much better exposure data than the second. At best the fluorspar miner study should only be used as a qualitative confirmation of the association of an excess of lung cancer among persons exposed to unusual amounts of radon daughters.

The paucity of specific measured data makes it highly improper to use it in any quantitative manner. The procedure of averaging the fluorspar miners with the other groups introduces significant bias on the high side in the predicted lung cancers that may result from exposure of the public to radon daughters coming from uranium tailings piles. Averaging the result of the two studies is similar to averaging two vehicular traffic counts on a given road with one count based on the results of a properly functioning mechanical counter and the other based on a local resident's guess as to how many vehicles use the road.

By using the adjusted 1972 BEIR report average absolute risk the assumption is made, but not stated, that the smoking habits among the populations for which projections are made will be the same as those among the miners studies. This is a grossly incorrect assumption as the data in the studies clearly show that the miners in both studies smoked significantly more than the U.S. male population.

Women smoke less than men, so that when the BEIR report figures are used for the public the assumption is made, but not stated, that women smoke as much as the uranium miners. In the U.S. uranium miners study, their excess smoking habits were calculated to raise their lung cancer rate 49%. Thus another conservative bias is introduced.

Furthermore, the results of the U. S. uranium miners study show that nonsmokers exposed to radon daughters at low exposures may have a much lower risk of getting lung cancer and they have a much longer induction-latent period (about 7 years longer) than smokers similarly exposed. Through 1978 approximately 230 of the 3366 men in the white underground uranium miners study group have developed or died of lung cancer and of these 14 were classified as non-smokers by the U.S.P.H.S., although one confirmed that he had smoked 6-10 cigars per day for 28 years. (Personal communication from Dr. V. E. Archer.) Thus only 6% of the 230 who developed lung cancer were non-smokers, whereas 28% of the 3366 were non-smokers. The average induction-latent period of the non-smokers was 7 years longer than that for the smokers.

Through 1978 approximately 16 of the 780 men in the U.S. Indian uranium miner study group have developed or died of lung cancer and of these 6 are classified as non-smokers by the U.S.P.H.S. (Personal communication from Dr. V. E. Archer.) Thus only 38% of the 16 who developed lung cancer were non-smokers whereas 63% of the 780 were non-smokers, and another 15% smoked only 0.1 pack of cigarettes per day.

Because the Indian group numbers are small and follow-up time on them has not been carried on as long as on the white study group, the Indian figures may yet be subject to significant change, but it is clear that in both groups the incidence of lung cancer among non-smoking uranium miners is very much less than among uranium miners who smoke.

The argument has been made that the non-smokers exposed to radon daughters do not have a lower risk of developing lung cancer but that they do have a longer induction-latent period than smokers similarly exposed. If the non-smokers have a lower risk, overestimating the number of smokers in the general public has the effect of seriously biasing to the high side the possible lung cancer cases arising out of exposure to tailings pile originated radon daughters. If the non-smokers simply have a longer average induction-latent period, the effect is similar because the longer induction-latent period will result in a higher proportion of deaths from competing causes.

Another assumption made but not stated is that the 4 state lung cancer incidence rates used to calculate the expected cases in the U.S. uranium miners study apply to the U.S. as a whole. This is an incorrect assumption. National averages run 40 to 50% higher than the 4 states used. Similar unstated assumptions are involved in using the Canadian, British and Japanese rates involved in the fluorspar miners study, the spondylitis patients study and the Hiroshima-Nagasaki survivors study.

Another fact that requires comment is the basic assumption made, but not stated, that the relationship between mortality from excess lung cancer due to exposure to radon daughters and mortality from competing causes of death remains constant. The miner studies were of individuals exposed at high radiation levels. For instance, the mean exposure in the uranium miner study was 475 rads per person, about twice as much as that for the fluorspar miners and these (after the improper averaging) resulted in the previously cited figure of 2 cancers/10^6 person years/rem. This mortality rate at a mean exposure of some 475 rads per person is then extrapolated down to the very low radon daughter concentrations in the immediate vicinity of uranium tailings piles.

At these low exposures it is not a reasonable assumption that the relationship of mortality from excess lung cancer and from competing causes of death will be the same as at the very high level of exposure experienced by the miners. At the low dose rates around tailings piles, the induction-latent period for the appearance of lung cancer among those exposed can be significantly longer than among the miners studied. Longer induction-latent periods open the way for death from competing causes to be a higher percentage among the public than it was among the miners whose high exposure and smoking habits caused a shorter induction-latent period. This effect may be offset to some extent by the exposure of children among the public, but the overall effect of the longer induction-latent period among the public will be to increase the proportion of deaths from competing causes. The excess lung cancer deaths predicted in the GEIS, therefore, are all higher due to this factor than will actually be experienced.

The argument is made in the 1975 paper by V. E. Archer and E. P. Radford referred to in the 1976 NAS report that radon daughters are more efficient at producing lung cancer at low dosages (below about

100 WLM or 50 rads per lifetime) that at higher dosages, and than in extrapolating down from the U.S. uranium miners level of exposure to lower levels that the linear-no-threshold dose-response assumption will predict a falsely low mortality. The absolute risk at these lower exposures, therefore, would be greater than that derived from the linear-no-threshold theory. This Archer-Radford argument is based on their analysis of published data on uranium miners in Canada and Czechoslovakia, and of non-uranium miners exposed to low levels of radon daughters in Sweden. Numerous calculations had to be performed on the basic data from these different countries because the data were not all available in the same terms and the assumptions involved in each of these calculations have not yet been published and subjected to review by the scientific community. Thus the argument should not be accepted by NRC as scientific fact until publication and review have been accomplished.

Still another factor requiring comment is the assumption made, but again not stated, that the populations living in the vicinity of the tailings piles never leave the zones for which predicted excess lung cancer calculations are made. This is not a reasonable assumption, either. Assuming that no one in the time periods involved will leave these zones to work, to go on vacation, to visit relatives, to go to school, college or university, to go shopping, to go to sports events or other entertainment, etc. makes the calculations easier, but is unrealistic. The effect of this assumption is to predict unrealistically high dose rates among the population studied. A proper allowance for absence from the zones of calculation will result in lower dose rates and total dosages, with consequent longer induction-latent periods and higher deaths from other causes as already discussed. The overall effect of this assumption is to again overstate the predicted excess lung cancer deaths versus those that actually will be experienced.

A number of other factors have been ignored or incorrrectly assessed. The concentration of radon daughters in a dwelling has been assumed to be directly proportional to the concentration of radon in the air outside, and to vary in proportion to changes in the external radon concentration. This factor is the result of a number of readings taken in residential buildings. Apparently the radon concentrations have been calculated for various outdoor points in the immediate model mill areas, in the model mill region, and in the continent and the corresponding indoor radon daughter levels derived from this basic assumption. No account is taken of the fact that there is a significant variation in interior radon daughter levels due to seasonal, construction, and geographic factors. During warm weather many homes and buildings have many open windows and doors resulting in good ventilation, but during cold weather the windows and doors are closed and ventilation is restricted. Buildings and homes built in warm and temperate climate areas have much more air movement than those built in areas with cold winters. This can cause a significant change in the radon daughter levels. Victor E. Archer, M.D., has estimated that because of these factors the radiation contribution from radon in the north of the U.S.A.

is twice that in the southern U.S.A. with intermediate contributions in the central states. (See "Geomagnetism, Cancer, Weather and Cosmic Radiation" by Victor E. Archer, published in Health Physics, Pergamon Press in 1978, Vol. 34, page 239.)

Furthermore, radon daughter concentrations will vary with the height of a building due to the contribution of radon from the ground beneath a building. This contribution is greatest on the floor contiguous to the ground and decreases rapidly in higher stories. (See Table 13, page 80, "Ionizing Radiation: Levels and Effects," a Report of the United Nations Scientific Committee on the Effects of Atomic Radiation to the General Assembly, Volume I: Levels, 1972). Thus populations living in multiple story apartment buildings have progressively lower radon daughter levels on each successively higher floor. This factor has been ignored also, leading to a bias in the direction of overstating the number of lung cancers predicted to result from radon released from tailings piles.

Lung cancer rates may vary significantly for different races in the U.S. due to differences in culture, diet, smoking habits, and similar factors. The 1972 BEIR report in arriving at an average absolute risk of 1 case/ 10^6 person year/rem (raised to 2 in the GEIS) used only the results from the U.S. white uranium miners study, but published the results from a study of a smaller, non-white group. The absolute risk for the non-white uranium miners was 0.07 cases/10^6 person year/rem versus 0.63 for the white group. (See page 151 of the 1972 BEIR report.) (These differences may be explained possibly by two facts: 1) the Indian group smoked much less than the white group; and 2) the follow up period was much shorter.) The GEIS makes no attempt to account for either the different background lung cancer rates for different races, or for the significant difference in the lung cancer rates between the two groups of irradiated uranium miners. This assumption that the health effects will be the same for all races may be another conservative factor that is compounded.

There are thus a number of assumptions and factors which are biased in the direction of overstating the expected lung cancers among the public due to uranium tailings pile originated radon daughters by various percentages. When these pyramided percentages are multiplied out, the result is that the predicted lung cancers among the public are overstated by 500 to 700%. There may be a few assumptions and factors that are biased in the opposite direction, but it is extremely doubtful that they would have as significant a cumulative bias. This lack of balance exceeds the bounds of normal, precautionary "conservatism."

Table 6.16 (on page 6-41) of the GEIS shows somatic effects broken down by 3 organs - lung, bone, whole body and totals, but the last column on the right entitled "Natural Incidence of Cancer" gives only the total figure of 9,900. It would be useful to have this broken down into the lung, bone, and whole body categories. The lung and bone cancer figures could be derived from percentages the way the 9,900 figure is derived (as noted in footnote c) and the balance attributed to whole body and a footnote added to explain the procedure.

Table 6.33 (on page 6-65) does not have any figures for "Range of Typical Natural Background Values" for WL Concentrations Outdoors and Indoors. These should be supplied so that a reader can know from the balance of the table what the increase due to the model uranium mill(s) is predicted to be.

The figures for uranium mills in Table 6.41 (page 6-74) do not agree with those in Table 6.39 (page 6-72) in the total line for the years 1978-2000 and there seems to be no reason why they should not. The last sentence of 6.43 (on page 6-73) uses the figures from Table 6.41 and does not mention those in Table 6.39. Although the difference in the figures is small, there seems to be no reason why they should not be the same in all three places.

In addition, Table 6-39 should have an additional column showing background or total deaths predicted so that the reader can determine what % the predicted premature deaths are of the predicted background or total deaths. A column showing this percentage would be another improvement in the table.

6. In general the predicted deaths due to the model uranium mills(s) are a miniscule percentage of the total background deaths in the various categories analyzed in spite of the pyramiding of all the "conservative" assumptions involved. If the predicted deaths were to be recalculated after elimination of all these "conservative" assumptions, the results probably would be at least an order of magnitude less than shown in the GEIS. The text and conclusions of the GEIS should explain clearly the percentage that the predicted deaths are of the totals and that their numbers have a large margin for error on the side of predicting more deaths than would actually occur if the model mills were the only ones built versus margin for smaller errors on the side of predicting too few.

Another matter that should be addressed is that of cost effectiveness. Some analysis should be made of the cost per future potential cancer avoided by covering uranium tailings piles as recommended in the GEIS and per person-year of additional life that a potential cancer avoided will yield. This concept is now being used in other fields as the attached advertisement by General Motors Research Laboratories shows.

The evaluation of the cost per person-year of potential additional life is a social matter and at first thought seems a repugnant concept, but a little reflection reveals that similar evaluations are being made all the time. For instance, why do we not have pedestrian overpasses or underpasses at all busy vehicular street crossings instead of conventional stop lights? These would undoubtedly save some lives, resulting in some potential additional person-years of life. The answer is that a social judgment has in some way been made that the costs of the over or underpasses per potential additional person-year of life is so high that they are not acceptable to our society. Many similar examples exist.

The subject of radiation exposure and the possible causation of cancer always arouses emotional reactions which tend to override and mask many of the true facts involved. Before decisions on how much money should be spent on uranium tailings piles are made, an effort should be made to see that these decisions are based on objective and accurate perspectives and follow the social criteria used in making similar decisions in other aspects of our society.

How to figure the cost of living ...a longer life.

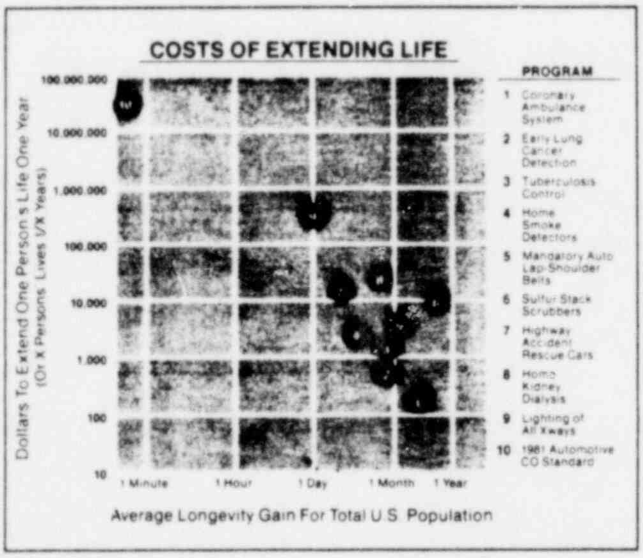
What's the fairest way of allocating the nation's limited funds to reduce various risks to human life and health? A loaded question, to be sure.

One way of evaluating a given risk-reduction program is to compare estimated costs with expected benefits, both measured in dollars. But this kind of analysis is controversial. For one thing, it requires placing a price on life itself.

Here at the General Motors Research Laboratories, societal analysts have developed a method which avoids that problem completely. It focuses on longevity and rests on the simple logic that since all life inevitably ends, no amount of risk reduction can *save* lives . . . only *lengthen* them.

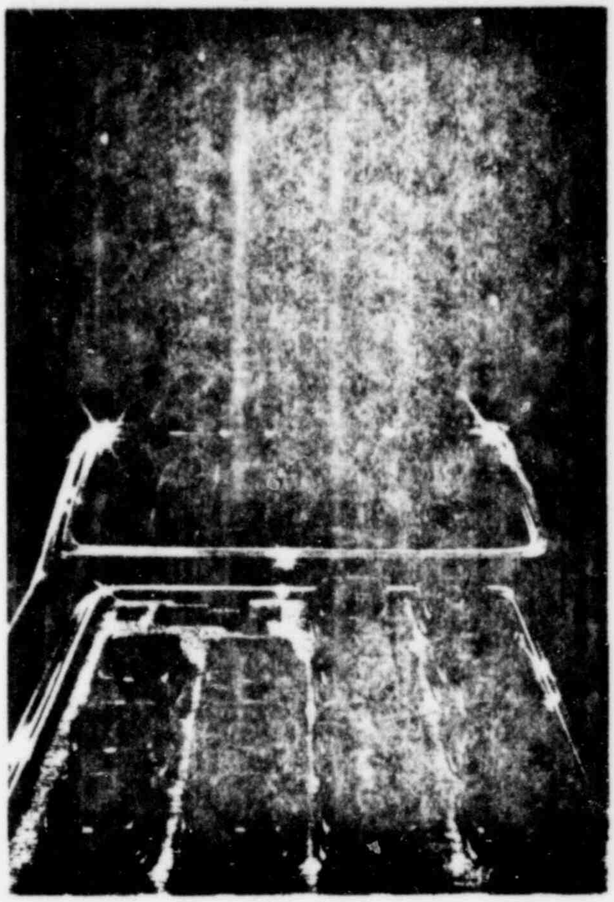
The method involves using the extensive data for all categories of mortality risks and determining the effect on longevity of each category independently. The results can be summarized for each risk by the equation: Average Years Of Longer Life = 0.2 x Annual Deaths Per Million Population.

This equation serves two purposes. First, it provides a perspective of days or years gained from risk-reduction programs. Second, combined with cost estimates, it helps rate the effectiveness of those programs.



To illustrate its utility, we performed a study to compare the cost-effectiveness of several medical, environmental, and safety programs presently under serious consideration. The chart above shows the extreme variation in the costs of extending life by implementing those options.

Through such unbiased comparisons, policymakers can obtain a clearer picture of which programs offer the greatest potential gain for a fixed budget and, thereby, have a better basis for decision.



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Part III

A. Radiological Aspects

2. Improper Assessment of Background Radiation Levels

COMMENTS ON RADON EMISSION CRITERIA CONTAINED IN THE DRAFT GENERIC ENVIRONMENTAL IMPACT STATEMENT (GEIS) ON URANIUM MILLING, NUREG-0511, APRIL 1979

Keith J. Schiager, Ph.D.

General

The draft GEIS purports to collect, synthesize, analyze and interpret information related to the actual and potential environmental impacts of uranium milling operations. However, the justification presented in the GEIS for establishing the maximum radon emanation rate and the minimum cover thickness criteria for reclaimed tailings piles is not based upon physical or biological data. Instead, the criteria for tailings reclamation are based upon a philosophical attitude expressed in NRC staff decisions which ignore physical realities represented in the draft GEIS and elsewhere in the available literature. Consequently, my disagreement with the radon control criteria presented in the draft GEIS is primarily with the philosophy of radiation protection used by the NRC staff rather than with the data base presented in the draft GEIS.

Legitimate Criteria for Radon Emission Controls

One important criterion for radon control is to limit the exposure to any nearby individual to a value that is less than the current exposure limits and also within anticipated future limits. The current concentration limit for radon-222 in unrestricted areas resulting from releases from a licensed facility is 3 pCi/L (10 CFR 20). This limit is reduced to 1 pCi/L if a "suitable sample of the population" is exposed. The "suitable sample of the population" is not defined, but it is usually interpreted to mean communities of at least a few hundred or thousands or people, which would be likely to contain a representative distribution by ages and health conditions.

The Surgeon General's Guidelines (10 CFR 712) promulgated in 1970 for use in the remedial action program in Grand Junction, Colorado required that remedial action be undertaken for residences exhibiting an annual average radon daughter concentration of greater than 0.05 WL. No remedial action was indicated for average indoor concentrations of less than 0.01 WL. In the intermediate range, remedial actions could be suggested at the discretion of state authorities. Although these limits apply to corrective as opposed prospective control measures, the range of concentrations separating the significant from the insignificant is still instructive. The appropriate value for a prospective exposure limit probably lies somewhere between 0.01 and 0.05 WL.

A second legitimate criterion for controlling radon emissions is the limitation of total health risk to the population. Since there is no recommended or regulatory limit for population exposures, this criterion must be based upon the principle that all exposures should be reduced to levels that are as low as reasonably achievable (ALARA) taking into consideration all relevant social and economic factors. This principle obviously demands a detailed cost-benefit analysis that includes all future costs as well as all future benefits. Neither of these criteria are properly utilized in the GEIS.

The primary benefit of the proposed radon control measures is presented in the GEIS as the prevention of approximately 9800 cases of lung cancer to the year 3000, or about 10 cases per year. I will show that this calculated number of lung cancer cases attributable to the radon emissions from uncontrolled tailings piles is grossly exaggerated, resulting in an unrealistic assumption of benefits.

The only cost of radon control presented in the GEIS is the direct cost of covering the tailings piles. While this cost may be seriously underestimated, that is not the major deficiency in the cost estimate. The GEIS should address the total future cost to consumers of electricity that will result from various incremental increases in the cost of fuel. If the benefits are to be calculated for the long-range future, costs should likewise include the future compounding of current production costs.

Calculation of Benefits from Radon Emission Reduction

The GEIS assumes that population radon exposures from tailings piles if left uncovered would result in approximately 9,800 premature cancer deaths during the next 1000 years. By reducing the emission rate from 450 $pCi/m^2 \cdot sec$ to 2 $pCi/m^2 \cdot sec$ above the natural background rate, the premature cancer deaths from this source would be reduced to 42 in the same 1000 year interval (page 12-12). This calculation is based on the linear non-threshold model of biological effects and on the risk estimates used by the BEIR Committee*. However, both the linear dose-effect relationship and the numerical risk estimates were derived from data on uranium miners exposed to concentrations of radon and its decay products orders of magnitude above those to which general populations are exposed. Other environmental conditions to which the miners in these studies were exposed also were quite different from those to which average population groups are exposed. As a consequence, the risk estimates tend to ignore the very real contributions of carcinogenic co-factors to the total risk of lung cancer.

The BEIR report included calculations of both absolute and relative risk values. Absolute risk is defined as the "product of assumed relative risk times the total population at risk; the number of cases that will result from exposure of a given population." Absolute risk is simply a method of converting the ratio of <u>observed</u> to <u>expected</u> cases in a study population to the number of cases that would be produced per unit population (collective) exposure. The use of absolute risk values in this manner implies that each increment of exposure will produce the same total biological effect (e.g. cases of lung cancer) regardless of the actual level of exposure

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*Advisory Committee on the Biological Effects of Ionizing Radiation, The Effects on Populations of Exposure to Low Levels of Ionizing Radiation, National Academy of Sciences - National Research Council, 1972.

or the presence of other carcinogens. The absolute risk model is, therefore, the only truly linear model for the dose-response relationship. However, recent analyses* of lung cancer incidence among uranium miners indicate that the relative risk model best describes the data.

Relative risk is defined in the BEIR report as "the ratio of the risk in those exposed to the risk to those not exposed (incidence in exposed population to incidence in control population)." It is derived from the ratio of <u>observed</u> to <u>expected</u> cases in the population studied. When a relative risk derived from one population is applied to another population, or to other exposure conditions, the projected number of additional health effects becomes dependent upon the assumed normal incidence of that health effect in the second population. Consequently, the relative risk model implies that each added increment of exposure will produce the same <u>percentage</u> increase in biological effects above those that would occur at the preceding level of exposure. This relationship is easily recognized as an exponential model, e.g. as the basis for compound interest. The dose-response curve is approximately linear only for very small differences in exposures, and only when all other contributing factors remain constant. A linear extrapolation from the uranium miners' data to general populations using relative risk estimates is totally unjustified.

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*Ellett, W.H., Exposure to Radon Daughters and the Incidence of Lung Cancer presented at the American Nuclear Society meeting in San Francisco, CA, December 1, 1977.

Recent discussions of lung cancer risk emphasize the initiator-promotor theory of carcinogenesis developed by Brodsky* that involves sequential actions on a susceptible cancer control center (perhaps a single cell) in which the second action is conditional upon the first action having been completed. This model can account for the observed non-linearity of the dose response curve for certain kinds of radiation exposures and observed cancers. For example, it can account for the observation by Archer, et al** that the risk of lung cancer to uranium miners appeared to increase when the same total exposure was received over longer periods of time. It can also account for the fact that lung cancer has increased from approximately 10 per year per million population in the early part of the 20th century to more than 400 per year per million population today. This increase was obviously not due to changing environmental radon concentrations, although radon may act as either an initiator or promotor of lung cancer. If radon can act alone as a carcinogen, the absolute risk factor certainly could not exceed the lung cancer rate early in the century even if it was assumed to be completely due to radon. However, if the relative risk model is valid, the incidence of lung cancer would increase approximately in proportion to the increase in radon concentration, but only because of the

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*Brodsky, A., A Stochastic Model of Carcinogenesis Incorporating Certain Observations from Chemical and Radiation Dose-Response Data, Health Physics 35:421, June 1978.

**Archer, V.E., E.P. Radford and O. Axelson, Radon Daughter Cancer in Man: Factors in Exposure-Response Relationships, presented at the Annual Meeting of the Health Physics Society, Minneapolis, MN, June 1978.

presence in the environment of other carcinogens which are primarily to blame for the increased incidence observed over the last half century.

During the past 50 years the U.S. population has been involuntarily subjected to massive increases in some types of atmospheric pollution from the increased use of automobiles. At the same time, the population has also been exposed to a tremendous increase in tobacco smoke inhalation. Consequently, the current lung cancer incidence rate upon which relative risk calculations are based is the result of very recent exposures to environmental concentrations of carcinogenic co-factors. If the massive efforts now underway to reduce these sources of inhaled carcinogens are successful, the incidence of lung cancer should be drastically reduced. On the basis of the relative risk model, the fractional contribution due to radon exposure would also be reduced proportionately. If the impact of radon exposures is calculated on the basis of cleaner air and low cigarette consumption, comparable to conditions existing early in the century, the projected number of premature cancer deaths occurring during the next 1000 years would be about 250 with no covering of tailings and approximately 1 with the emission rate reduced to 2 $pCi/m^2/sec$. On an annual rate, the base-case scenario with no control would represent 0.25 premature cancer deaths per year.

The authors of the GEIS obtain an unrealistically high estimate of the benefit of radon control by averaging the absolute and relative risk estimators derived from uranium miners and treating this average as an absolute risk. They have ignored the recent evidence that indicates that lung cancer can be best described by the relative risk model, and they have ignored the important implications and proper application of the relative risk model.

Criteria Used in the GEIS for Radon Control

The proposed radon emission criterion of 2 $pCi/m^2 \cdot sec$ is not based upon either the necessary protection of individuals or on considerations of public health risks. Instead, this criterion is based upon "the objective of returning tailings disposal sites to conditions which are reasonably near those of surrounding environs" (page 17). Using this objective "eliminates the option of controlling radon at much higher levels, such as 10-100 $pCi/m^2 \cdot sec$, since background flux rates average between about 0.5 and 1.0 $pCi/m^2 \cdot sec$." Elsewhere in the GEIS (page 12-10 and Appendix 0) the average radon flux is assumed to be 0.5 to 1.3 $pCi/m^2 \cdot sec$, with an upper limit of 3.5 $pCi/m^2 \cdot sec$. These statements illustrate either the misunderstanding or the deliberate misuse of environmental date. The authors of the GEIS have averaged out all of the variability of the real world.

I would concur with the general objective of leaving tailings pilings in such a condition that radon release rates, and the potential for radiation exposures, are within the range of natural background. Such a requirement would assure that present or future generations would not be subjected to risks that are different either in kind or in magnitude from those imposed by nature. This requirement should not imply, however, that all radiation sources under human control must be reduced to the average found in nature. Instead, the impacts of human activities should be compared with the distribution (or range) of comparable impacts from natural sources.

Natural Radon Sources and Exposures

An extremely wide range of environmental conditions is observed in nature. This is particularly true for natural radioactive materials and radiation exposure rates. The commercial extraction of various minerals in specific locations is simply one illustration of this fact. No mining company would be in business if the only ore available contained the average mineral concentration found in the earth's crust.

Environmental radon sources have been observed to conform to a log-normal distribution. In such a distribution, 50% of the observed values are greater than or equal to the median value; 16% exceed the median multiplied by the geometric standard deviation (GSD); 2.3% exceed the median multiplied by the square of the GSD; 0.13% exceed the median multiplied by the cube of the GSD; etc.

By referring to geometric mean concentrations of radon (page C-5), the authors of the GEIS have indirectly acknowledged that radon concentrations are log-normally distributed. However, they have ignored that fact when addressing the proposed levels of radon control in relation to natural radon sources and exposures.

The GEIS assumes an average indoor concentration of about 900 pCi/m^3 for western regions (page C-5). This value is derived from an estimate of outdoor radon concentrations in western regions of 240 pCi/m^3 and an extrapolation from indoor-to-outdoor ratios observed in the New Jersey and New York area. Shearer and Sill* observed outdoor background radon concentrations of 800 pCi/m^3 in Grand Junction, 500 pCi/m^3 in Durango, 340 pCi/m^3 in Monticello and 380 pCi/m^3 in Salt Lake City. All of these background concentrations are substantially higher than the 240 pCi/m^3 assumed in the GEIS. Measured indoor concentrations in the United States have ranged from 5 to 4800 pCi/m^3 (NCRP-45, 1975)**; the 10 average values reported by NCRP have a geometric mean of 225 pCi/m^3 and a geometric standard deviation of 3.

Indoor radon concentrations vary not only with location but with type of construction and ventilation rates. Measurements of indoor radon progeny concentrations at <u>background</u> locations in Grand Junction made by the Colorado Department of Health*** exhibited a geometric mean of 0.072 WL with a geometric standard deviation of 1.7. This radon progeny concentration correlates with a radon concentration of 1400 pCi/m^3 if the equilibrium factor is 50% as assumed in the GEIS or a concentration of 900 pCi/m^3 if the equilibrium fraction was 80%. It can be assumed that a geometric standard

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*Shearer, S.D. and C W. Sill, Evaluation of Atmospheric Radon in the Vicinity of Uranium Mill Trailings, Health Physics 17:77, 1969. Also see Addendum.

**Natural Background Radiation in the United States, National Council on Radiation Protection and Measurements, NCRP Report No. 45, 1975.

***Peterson, B.H., Background Working Levels and the Remedial Action Guidelines, presented at the Radon Workshop, Health and Safety Laboratory, New York City, February, 1977 (HASL-325, 1977).

deviation (GSD) as low as 1.7 would only occur within a single community containing many houses of similar construction and subjected to equal meteorological conditions. On a regional basis, the GSD would be expected to be larger than 2, but probably not as large as 3.

If one assumes a geometric mean concentration of 900 pCi/m^3 for the western region and a geometric standard deviation of 2.2, the resultant distribution would indicate that 15% of the homes in the region would have average indoor concentrations greater than 1980 pCi/m^3, 2.5% would have concentrations exceeding 4400 pCi/m^3 and 0.13% would have concentrations exceeding 9600 pCi/m^3. The later would be equivalent to a radon progeny concentration at 50% equilibrium of 0.05 WL.

Although there has been no extensive survey of indoor radon and radon progeny concentrations in the United States, surveys conducted in other countries indicate concentration distributions comparable to the hypothetical distribution proposed above. For example, Steinhäusler, et al* reported on 4600 measurements of indoor radon concentrations in Salzburg, Austria. They observed an arithmetic mean value of 410 pCi/m^3 with a range from less than 50 to 5160 pCi/m^3. Over 6% of the measurements exceeded 2000 pCi/m^3 or approximately 4 times the mean value. The skewed distribution of the data appear to reflect a lognormal distribution, although they were not analyzed in that manner. A survey conducted

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*Steinhäusler, et al, Local and Temporal Distribution Pattern of Radon and Daughters in an Urban Environment and Determination of Organ Dose Frequency Distribution with Demoscopical Methods, <u>in</u> The Natural Radiation Environment III Symposium, Houston, Texas, April 1978.

in Sweden* showed concentrations in seven types of structures ranging from less than 700 to 15,900 pCi/m^3. For the seven structural types, the average concentrations ranged from 1500 to 11,100 pCi/m^3. A study of the contributions from structural materials to indoor radon inventories in England and Scotland** also produced a lognormal distribution with a geometric standard deviation of 3.1. Although the indoor radon or radon progeny concentrations were not reported, the study does indicate the validity of the lognormal distribution and provides evidence of the expected wide range of concentrations (GSD = 3.1).

Because of averaging factors, outdoor radon concentrations normally exhibit less variability than indoor concentrations. However, it is expected that radon flux from the ground surface would exhibit a highly variable lognormal distribution owing to the inhomogeneity of radium bearing minerals and soil conditions. An average radon flux in the range of 0.5 to 1.3 pCi/m^2·sec is assumed in the GEIS (page 12-10 and Appendix O); however, the upper end of the range is incorrectly inferred to be 3.5 pCi/m^2/sec. The reason for this incorrect inference is primarily the small number of flux measurements reported in the literature and the fact many averages were not viewed as representing the expected

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*Swedjemark, G.A., Radon in Swedish Dwellings, ibid.

**Cliff, K.D., Measurements for Radon-222 Concentrations in Dwellings in Great Britain, ibid.

lognormal distribution. If a GSD of 3 is assumed (it seems reasonable that all land surfaces will show at least as much variability in radon emission as do building materials in England), one can predict that 15% of the land area would exhibit a radon flux greater than 1.5 pCi/m^2/sec, 2.3% would exceed 4.5 pCi/m^2/sec, 0.13% would exceed 13 and 0.003% would exceed 40 pCi/m^2/sec. The total land area expected to be occupied by tailings piles by the year 2000 would be approximately 0.0013% of the area of the contiguous 48 states (approximately 80 currently active and projected mills plus approximately 20 currently inactive tailings piles, each covering 250 acres).

Within the objective of assuring that radon emissions from tailings piles are within the normal range of natural background for areas of comparable size within the United States, radon emission control to a level of 25-30 pCi/m$^2\cdot$sec would appear reasonable.

Radiation Exposures Predicted by the GEIS

The calculations of radiation doses to individuals and populations are presented in the GEIS only to justify this arbitrarily selected emission limit by showing that all resulting doses are truly negligible. For residents of a home built directly on a reclaimed tailings pile, an extremely unlikely occurance, the annual average indoor exposure was calculated to be 0.0036 WL (page 9-27). "Other reasonable assumptions if stacked up in the extreme directions could lead to a range of 0.0006 to 0.006 WL" resulting from a flux of 2 pCi/m^2/sec from a covered pile below the structure. For the radon progeny equilibrium ratio assumed throughout the GEIS, 0.036 WL implies an average indoor radon concentration of 720 pCi/m^3. The range of calculated concentrations for this worst case exposure situation are all within the range of normally occurring concentrations. For other exposures to individuals under more likely conditions, the indoor radon progeny concentrations would be extremely small fractions of the naturally occurring concentrations (page 9-27). With no cover material (flux = 450 pCi/m^2/sec), the annual lung dose commitment to the population of the model region would not exceed 1% of the dose from naturally occurring radon. Reducing the average emission rate to a few pCi/m^2·sec is assumed to limit the contribution from mill tailings to about 0.001% of the total population dose from radon (page 9-27).

Even if radon emissions from tailings piles are not reduced to 2 pCi/m^2·sec above the <u>average</u> background, they can be within the true <u>range</u> of background. Based upon the observed distribution of radiation sources in nature, the area of the United States with radon emissions greater than 30 pCi/m^2·sec is at least 10 times the total area of all tailings piles predicted by the year 2000.

Thickness of Cover Material

A minimum thickness of 3 meters of cover material is proposed in the GEIS (pages 17 and 12-19). As has already been shown, this thickness cannot be justified on the basis of reducing the risk of lung cancer. Furthermore, the amount of cover material required for reducing radon emissions is overestimated in the GEIS. The calculations (Chapter 11 and Appendix P) are based on assumptions that do not agree with empirical observations. Measurements made by the U.S. Environmental Protection Agency* at a partially reclaimed tailings pile indicated that approximately 3 feet of earth cover reduced the radon emission by a factor of 8. This finding would imply a reduction by a factor of 64 for 6 feet and a factor of 500 for 9 feet (less than 3 meters). The cover used in this case was local soil and included no clay. For other comparable circumstances, a cover layer of 3 to 4 feet of local soil would reduce radon emissions to a level that would be within the range of natural background.

Long Term Physical Isolation and Stability

In addition to radon emission control, tailings piles need to be covered and stabilized to reduce risk of long term wind and water erosion. Any specified type and thickness of cover material will provide varying degrees of erosion control depending upon local topography, meteorology, etc. On the other hand, no specified thickness of cover material (within any reasonable limits) can provide complete assurance against erosion forever. Furthermore, no specified covering can provide complete assurance against human utilization or intrusion at some future date. Consequently, the criterion of long term isolation can be satisfied only on a

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*Hans, J.M., et al, Estimated Average Annual Radon-222 Concentrations Around Former Uranium Mill Site in Shiprock, NM, USEPA, Report No. ORP/LV-78-7, 1978.

probablistic basis.

The GEIS does not address the improbability of the use of a reclaimed tailings pile as a residential site, nor does it address actual erosion rates of surface materials at potential tailings locations. Instead, it presents only the staff judgement that 3 meters of cover is required to assure long-term isolation. There is no analysis in support of this judgement, nor are there any analyses of the consequences of using thinner cover layers. Such a judgement without supporting evidence or analysis, is totally arbitrary.

Proposed Revisions to the GEIS

1. The GEIS cannot serve as a valid basis for proposed regulations. It should evaluate alternative levels of radon control and tailings isolation and evaluate the costs and benefits of those alternatives. The Environmental Protection Agency is charged with establishing environmental radiation standards; the NRC is charged with promulgating regulations that will comply with EPA criteria. It is premature for the NRC to propose specific radon emission regulations prior to the publication of EPA criteria and standards.

2. The GEIS should utilize the most recent and best available dose-response models and risk estimates for calculating the benefits of radon emission controls. The implications of the relative risk model with regard to carcinogenic co-factors, and in the light of initiator-promotor models of carcinogenesis should be recognized

and utilized.

3. The GEIS should compare the calculated release rates from uranium mill tailings with the natural distribution of radon flux, not simply with the average.

4. The GEIS should calculate the impact of uranium milling on the assumption that appropriate regulations for radon control will assure that the resulting exposure conditions will be within the range of natural background conditions. A limit of 25-30 $pCi/m^2 \cdot sec$ would probably meet this criterion.

5. The GEIS should address the variabilities and probabilities related to environmental conditions and the potential for human exposures in uranium milling regions. It should point out the variations in agricultural practices, population densities, etc. that are likely to be found in the vicinity of uranium mills in the future. It should classify the potential mill sites or regions of intensive uranium milling activities according to their potential for supporting significantly larger populations. It should address the probability (or improbability) of residences being built over tailings piles rather than simply assuming such an occurence in support of the proposed radon flux limit. The probability of such construction should be related to the potential for population growth in each region of expected uranium production.

6. The GEIS should address the continuing costs to the U.S. population of investing millions of dollars in covering of tailings piles. If health effects (incidence of lung cancer) are to be calculated for some extended future time period (e.g. 1000 years),

the costs of preventing such health effects should also be projected forward for the same time interval.

ADDENDUM

During the October 18, 1979, hearing in Albuquerque, the question arose as to the validity of background radon measurements in Grand Junction, Durango, Monticello and Salt Lake City.

The study reported by Shearer and Sill was a joint REC-USPHS study to determine the impacts from tailings piles. The investigations selected sampling locations at many distances and in all directions form the piles. Sampling locations away from the piles in the upwind directions were used as background stations. The analysis of the date was sufficiently sophisticated to verify the validity of the radon background for each locality. These radon background concentrations are valid for areas having substantial uranium deposits -- regardless of any mining or milling activities.

The fact that radon emissions and airborne concentrations are much higher in the vicinity of uranium deposits is routinely utilized in exploration for uranium. Air masses containing higher than normal (average) radon concentrations are traced back meteorologically to their sources.

K. J. Schiager

Part III

A. Radiological Aspects

3. Deficiencies in Dispersion and Dosimetry Modeling

Comments Concerning
the
Use of the UDAD Code
For Predicting the Radiological
Impact of Uranium Mills
(Revision One)

for

American Mining Congress

September, 1979

by

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Impact Environmental Consultants, Ltd.
1409 Larimer Square
Denver, Colorado 80202

Summary

The Uranium Dispersion and Dosimetry (UDAD) Code was used in the Generic Environmental Impact Statement to estimate operational individual and population dose commitments for the base case and alternative mill scenarios. It was also used in evaluating the effectiveness of alternative tailings pond management plans during and after reclamation. Because of the complexity of the systems analyzed there is an inherent need for a computer simulation model for these evaluations. However, the UDAD Code, in its current configuration, is not an exact enough tool to be used for these purposes.

The UDAD Code is a synthesis of a number of submodels. Analysis of the support documents for these submodels raises two major issues:

1. Several of the submodels either do not accurately represent the physical processes they are intended to model or are not state of the art for modeling those particular processes. This is particularly true for the submodels used to estimate source terms, to account for dispersion and deposition, to calculate ground concentrations, and to calculate vegetation, meat and milk radionuclide uptake.
2. Uncertainty is inherent in estimates provided by each of the submodels. Although never quantified in the GEIS documentation we have found some cases where this uncertainty is of orders of magnitude. In order to account for this uncertainty conservative assumptions and/or methods of modeling have been incorporated in many of the submodels to assure that risks to the public are not underestimated.

Conservatism within the Code is compounded when the conservative results of one submodel are used as input to other conservative submodels. UDAD Code dose estimates are estimated to be conservative by several orders of magnitude depending on specific situations. For example conservatisms inherent in only the dispersion, deposition and external dose submodels cause external dose equivalents at near receptors to be overestimated by a factor between 40 and 600.

Use of the Code as the final and exact source of dose estimates and as a basis for regulatory actions, as in the GEIS, does not represent use of "best available technology". Prior to issuance of the final impact statement the Code should be modified. Priorities for submodel modifications and for further research should be established by conducting a sensitivity analysis of the Code. Such an analysis would allow the NRC to identify those critical parameters which most affect Code output.

PREFACE

The intent of this report is to review the code used by the Nuclear Regulatory Commission (NRC) to predict the radiological impacts of uranium milling operations. The code is based on the Uranium Dispersion and Dosimetry (UDAD) Code originally developed by Argonne National Laboratory. The Argonne version of the code is documented in a report entitled The Uranium Dispersion and Dosimetry (UDAD) Code (NUREG/CR-0553, ANL-ES-72).

The NRC has revised the UDAD Code and has documented versions in the Draft Generic Environmental Impact Statement on Uranium Milling issued in April, 1979, and in the recently issued (May, 1979) Draft Regulatory Guide and Value/Impact Statement on Calculational Models for Estimating Radiation Doses to Man from Airborne Radioactive Materials Resulting from Uranium Milling Operations.[1] Both of these documents have been submitted to the public for comment. The following paper outlines an analysis of, and develops comments pertinent to both NRC documents.

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[1] Portions of the UDAD Code relating to source terms and atmospheric dispersion are not discussed in this Draft Regulatory Guide.

[redacted]

1. INTRODUCTION

The UDAD Code, as described in the abstract of the Argonne report, "... *provides estimates of potential radiation exposure to individuals and to the general population in the vicinity of a uranium processing facility...*" These estimates are used to evaluate compliance of uranium milling operations with NRC and Environmental Protection Agency (EPA) regulations, and to help satisfy National Environmental Policy Act (NEPA) requirements. Used in this manner, the UDAD Code is a tool which provides useful information to government agencies, the nuclear industry, and the public.

The following review focuses on the UDAD Code as an estimating tool. Individual components of the Code are examined separately and suggestions for improvement are offered. The Code is then discussed as a whole, including its direct applications, its application in the GEIS, and its application to specific sites. Recommendations are made for future applications. Finally, additional suggestions are offered concerning future development of the Code.

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2. SUBMODEL EVALUATIONS

Quantitative problems arise when applying the UDAD Code because it consists of a series of submodels. Within the framework of each individual submodel conservative assumptions have been made to assure adequate public protection. When these submodels are consecutively executed these conservatisms are compounded. As an additional factor affecting UDAD predictions, certain submodels are not necessarily the best available. Individual components of the UDAD Code were evaluated on the basis of these considerations.

2.1 Source Term Estimates

It is difficult to accurately predict the amount of emissions from a milling operation. Accurate estimates are necessary, however, since a model prediction is only as valid as its input data. Perhaps as important as correctly estimating the amount of effluent release, is to accurately represent the particle size distribution of particulate releases. In general, the smaller the particle (also depending on its density and shape) the further it will penetrate into the lungs, and the greater will be the dose delivered. If particle sizes are assumed to be too small (as the NRC has consistently done) predicted doses will be overestimated.

2.1.1 Ore Pad and Grinding

2.1.1.1 Particulates

In previous applications of the Code (e.g. the White Mesa project) the NRC staff has used a flux rate representing a percentage of the tailings pond flux. In the GEIS the dust flux from the ore pad is characterized as one metric ton per year having a uniform particle diameter of only one micron. To characterize all released material as being 1 μm in size is inaccurate and conservative. Neither of these methods accurately models the physical processes involved nor are the methods based on empirical data. *A more representative method approximating the size distribution should be employed.*

Methods for characterizing particle releases from grinding operations were also found to be overly conservative. To assume that all particles are 1 µm in size is again conservative since wet impingement scrubbers are not 100% efficient for particles sized between 0 and 50 µm. Particles released will range from 0 to 50 µm with an estimated average size value being closer to 5 µm. No empirical data is available to support selection of the 1 µm value. *A less conservative value should be used.*

2.1.2 Yellowcake Drying and Packaging

All yellowcake emissions are described as 1 µm in size. This is again conservative. As stated in the GEIS, particle size will depend on the particular processing method. The yellowcake drier is a primary source of effluent release in the uranium fuel cycle, therefore accurate source term estimates are required. *Further study is warranted to obtain the empirical data necessary for more accurate estimates.*

2.1.3 Tailings Pile

2.1.3.1 Particulates

Dust flux estimates are dependent on site-specific soil, vegetation, and moisture conditions. The submodel used in the UDAD for estimating the tailings pile dust flux is based primarily on a model developed by J. R. Travis (Travis, 1975, 1976). However, the submodel applied in the UDAD Code does not accurately represent dust resuspension from tailings ponds.

The importance of accurately specifying size distributions in relation to lung burden cannot be overstressed. Engelmann (Engelmann, 1976) recommended a method for calculating doses based on specifying the particle size distribution and integrating the dose received across that distribution. This method would require accurate estimates of initial distributions, and adjustment of those distributions during transport. However, this method could be implemented. A simpler version might be developed based on 4 or 5 size classes.

2.1.3.2 Radon

An inconsistency has been found between radon source terms for the base case as represented in the main report (450 pCi/m^2-s) and the calculated flux in appendix P(209 pCi/m^2-s). This discrepancy illustrates the uncertainties inherent in calculating radon source terms. The values used in UDAD are within the range of empirical and theoretical values currently available.

2.2 Air Dispersion, Plume Depletion, and Radon Daughter Ingrowth

2.2.1 Air Dispersion

The dispersion model incorporated into the UDAD Code is similar to the EPA Air Quality Display Model (AQDM) (National Technical Information Service, 1969), which is a Gaussian dispersion model. The AQDM model has in recent years been replaced by other Gaussian models such as the Climatological Dispersion Model (CDM) (Busse, 1973) and the Valley Model (Burt, 1977). The UDAD dispersion submodel was compared to these models and also evaluated in terms of recent modeling study results. Evaluation topics included:

* Mixing height estimates
* Building wake effects
* Applicability in complex terrain situations
* Use of Briggs dispersion coefficients
* Low wind speed conditions
* Plume trapping
* Accuracy of predictions at far distances

2.2.1.1 Mixing Height Estimates

The UDAD Code calculates an annual average mixing height which is applied in all stability conditions except extremely stable. *A desirable modification would be to calculate an annual average mixing height for each stability class.* This procedure is included in both the CDM and the Valley Models.

2.2.1.2 Building Wake Effects

No provision is made in the UDAD Code dispersion submodel to account for enhanced diffusion due to building wake effects. Depending on the particular site, this can be important for many or all mill effluents. Methods of accounting for building wake effects are presented in several papers (Huber and Snyder, 1978), (Letizia, et al, 1979). Realistic values for predicted concentrations can be obtained using such methods (Sagendorf, et al, 1979). *The UDAD Code should contain an option to account for this site-specific phenomenon.*

2.2.1.3 Complex Terrain

Many mill operations are located in complex terrain, therefore it is particularly important that the UDAD Code be accurate when applied to complex terrain situations. At present, the UDAD dispersion submodel does not contain any terrain modification provisions. Plumes are assumed to intersect and pass through barriers. The EPA Valley Model allows the plume to flow over and/or partially around an obstacle. Other terrain correction methods are available. *The NRC should consult with EPA modeling experts to develop an appropriate terrain modification procedure.*

In recent years studies have been conducted to validate Gaussian Models when applied in complex terrain (Hinds, 1970), (Hovind, Spangler, Anderson, 1974), (MacCready, et al, 1974), (Start, Dickson, Wendell, 1975), (Start, Ricks, Dickson, 1975). Results show that Gaussian Models (including the Valley Model) may underestimate diffusion by factors ranging from 2 to 15 depending on the particular situation. Underestimating diffusion frequently results in overestimating particulate concentrations. An alternate approach would be to employ a more sophisticated model such as a finite difference model or particle-in-cell model. Predictions made using these models correlate well with observed values. *The NRC may wish to consider the use of finite difference or particle-in-cell models.*

2.2.1.4 Briggs Dispersion Coefficients

The Briggs dispersion coefficients are intended for use in association with elevated stack sources (Turner, 1979). Use of these coefficients in the UDAD Code is inappropriate. *A review group sponsored by Oak Ridge National Laboratory has recommended that for surface level releases the most appropriate curves are those of Pasquill-Gifford with an adjustment for averaging time and with a roughness coefficient adjustment (Proceedings, 1978).*

2.2.1.5 Low Wind Speed Conditions

Studies of low wind speed conditions in rough terrain (common to uranium milling regions) demonstrate that Gaussian Models overestimate concentrations by up to a factor of 8 (Wilson, et al, 1976), (Sagadorf and Dickson, 1976). *The NRC has included a correction factor to account for this situation in their method for estimating potential accident consequences at nuclear power plants (Letizia, 1979) and should consider incorporating a similar correction into the UDAD Code.*

2.2.1.6 Plume Trapping

The method used in the UDAD Code to account for plume trapping is based on the work of Turner (Turner, 1970). A method more commonly employed in recent models is a reflection routine also described by Turner (Turner, 1970). *It is recommended that this method be incorporated into the UDAD Code dispersion submodel.*

2.2.1.7 Accuracy of Predictions at Long Distances

The UDAD Code calculates concentrations at distances up to eighty kilometers. The Pasquill-Gifford or Briggs dispersion coefficients are considered to be accurate only to distances ranging between 1 and 10 kilometers (Turner, 1970). Predictions become more uncertain as the distance increases.

2.2.2 Plume Depletion

The UDAD Code dispersion submodel accommodates for gravitational settling of particulates using a "tilted plume" factor (Van der Hoven, 1968). This factor is only applicable in "a well mixed atmospheric layer, such as is typical of daytime adiabatic conditions". *Therefore, this factor should only be used when neutral stability conditions exist.*

Another particulate removal mechanism incorporated into the UDAD Code is dry deposition. Deposition velocities vary with particle size, surface roughness, measuring height, wind speed, friction velocity, stability class, and other factors. In the UDAD Code five particle size categories are considered. A deposition velocity is assigned to each category which is used in all applications irrespective of specific site conditions. Hicks has developed a general equation for predicting deposition velocities taking into account particle size, stability, surface roughness, wind velocity, and other factors (Hicks, 1976). *Hicks' model or a similar general method for calculating deposition velocities should be incorporated into the UDAD Code.*

The UDAD Code accounts for losses due to deposition using a source term modification. Horst has shown that this method results in concentrations being overestimated by factors as high as 4 at receptors close to the source (10<km) (Horst, 1976). He has developed a model which more accurately depicts the deposition process. *The Horst Model requires greater computational resources but is more accurate and should be included in the UDAD Code.*

2.2.3 Radon Daughter Ingrowth

The time alloted for radon daughter ingrowth is calculated by assuming straight line transport to receptors. This is not an accurate representation of the physical processes involved. The wind does not blow continuously in one direction at one speed for a certain percentage of the year and then change to another speed and/or direction as is assumed. Although this approximation is commonly used to predict long term average pollutant concentrations, its use in calculating the time available for radon decay has not been justified. Data obtained during a field test of the UDAD Code conducted at the Anaconda Mill at Bluewater, New Mexico (Momeni, et al, 1978) exemplify this point.

Predicted radon and working level concentrations were compared to measured values. Predicted values generally exceeded measured values, and there was no correlation between the overpredictions of radon and overprediction of working levels. This might indicate that the straignt line transport model used to calculate working levels was not valid. *The approach used for calculating radon daughter ingrowth should be reviewed by dispersion modeling experts and further validation studies should be performed.*

2.3 Concentrations of Radionuclides in Environmental Media

2.3.1 Ground Concentrations

Ground concentrations calculated by the UDAD Model are a function of dry deposition rates, radioactive decay, and environmental weathering losses. Little information is available concerning weathering rates of the U-238 series radionuclides The value used by UDAD for λ_e, the decay constant, is equivalent to a 50-year half-lif When compared to experimentally determined values for cesium and strontium isotopes this value seems extremely large.

Studies by Rogowski and Tamura (1970) indicate that weathering rates of cesium-137 will vary seasonally and according to the type of vegetative ground cover. During their studies the average observed loss rate was a 60% reduction of initial concentrations during the first seven months following deposition. Krieger and Burman (1969) have studied the weathering rates of strontium-85 and cesium-134. During their experiments initial concentrations on exposed soils were reduced by 50% in the first three to four days and on protected soils 50% reductions occurred in 10 to 15 days. Subsequent half-lives were then observed to be 25 to 50 days.

The fifty year weathering half-life used in UDAD calculations is excessively long and leads to overestimated dose equivalents. *This value should be reviewed and revised.*

2.3.2 Total Air Concentrations

The resuspension submodel used in the UDAD Code was originally developed for use in the Liquid Metal Fast Breeder Reactor Environmental Impact Statement. Resuspended air concentrations are calculated using a time-dependent resuspension factor. The factor is assumed to decrease from an initial value of 10^{-5} to one of 10^{-9} over a period of 1.82 years. From that time on a constant value of 10^{-9} is assumed.

Experimentally determined resuspension factor values have varied from 10^{-2} to 10^{-13}, thus an uncertainty of several orders of magnitude is inherent in any selected value. The 10^{-5} and 10^{-9} values used in the UDAD Code are considered to be conservative choices. Assuming a constant factor of 10^{-9} for time periods greater than 1.82 years also represents a conservative approach to modeling resuspension processes. Predicted resuspension concentrations as presently calculated comprise a significant fraction of the total predicted air concentrations (approximately 37% of that predicted at the end of the first year). The resuspension model therefore significantly influences predicted inhalation and ingestion doses. The uncertainty inherent in the resuspension submodel undermines confidence in doses predicted by the UDAD Code.

2.3.3 Concentrations in Vegetation

Deposition onto vegetation is calculated based on total air concentrations. Deposition, however, has already been accounted for in calculating ground concentrations. The same deposition is assumed to fall again on vegetation. In addition, resuspended particulates are not subtracted from ground concentrations and are also reconsidered for deposition on vegetation.

The UDAD Model must account for these mechanisms in order to avoid repetitious data input which results in a conservative overestimate of external, inhalation, and ingestion dose equivalents.

The equation used for calculating vegetation concentrations is:

$$C_{vi} = D_i F_r E_v \frac{1-\exp\left(-\lambda_w t_v\right)}{Y_v \lambda_w} + C_{gi} \frac{B_{vi}}{p}$$

The values used in UDAD for key parameters were reviewed as follows:

1. Fr, P, and λ - Values used represent currently published values.
2. Ev - A value of 1.0 is used for above-ground plants and .1 for those below ground. These values are taken from Table III.6 of the Hermes Code documentation (Fletcher and Dotson, 1971) (See Table 2.1). Note that none of the values presented are related specifically to the U-238 series radionuclides. The above-ground vegetable values generally range between .05 and .1 and those for below-ground vegetables are less than .1. Use of maximum values introduces additional conservatism into the model. *Until further research can be conducted specifically for U-238 series radionuclides an average value would be more appropriate.*
3. Y_v - Values used in the UDAD Code are 2.0 kg/m² (freshweight) for crops and .75 kg/m² (freshweight) for pasture grass. These values

Nuclide	Grain[(a)] (T_g)	Potatoes[(b)] (T_c)
H-3	1.0 E+0	1.0 E+0
N-13	0	0
C-14	1.0 E+0	1.0 E+0
Na-22	5.0 E-2	5.0 E-2
Na-24	5.0 E-2	5.0 E-2
Cr-51	0	0
Mn-54	5.0 E-2	5.0 E-2
Fe-55	5.0 E-2	5.0 E-2
Fe-59	5.0 E-2	5.0 E-2
Co-58	5.0 E-2	5.0 E-2
Co-60	5.0 E-2	5.0 E-2
Ni-63	5.0 E-2	5.0 E-2
Cu-64	5.0 E-2	5.0 E-2
Zn-65	5.0 E-2	5.0 E-2
Sr-89	2.0 E-2	1.0 E-2
Sr-90	2.0 E-2	1.0 E-2
Zr-95	2.0 E-2	1.0 E-2
Nb-95	2.0 E-2	1.0 E-2
Mo-99	0	0
Ru-103	5.0 E-2	5.0 E-2
Ru-106	5.0 E-2	5.0 E-2
Te-132	1.0 E-1	1.0 E-1
I-129	1.0 E-1	1.0 E-1
I-131	1.0 E-1	1.0 E-1
I-132	1.0 E-1	1.0 E-1
I-133	1.0 E-1	1.0 E-1
I-135	1.0 E-1	1.0 E-1
Cs-134	1.0 E-1	1.0 E-1
Cs-137	1.0 E-1	1.0 E-1
Ba-140	2.0 E-2	1.0 E-2
La-140	2.0 E-2	1.0 E-2
Ce-141	2.0 E-2	2.0 E-2
Ce-144	2.0 E-2	2.0 E-2

(a) These same factors are also applicable to grain and above-ground vegetables consumed by humans.

(b) These same factors apply to root vegetables.

Table 2.1

TRANSLOCATION FACTORS FOR GRAIN AND POTATOES

Fraction of Radionuclide Deposited on Plant

Which Reaches Portion Eaten

(Taken from Fletcher and Dotson, (1971), Table III-6) are also based on Hermes Code documentation (See Table 2.2). It should be noted that only the yield values for root vegetables and strawberries, which constitute a small portion of total crops for most regions, exceed 2.0 kg/m². *A more satisfactory value for the UDAD Code would be a weighted-average of values for the crops actually grown in the region. This is a site-specific value. In the GEIS a value representative of the crops which are assumed to be grown should be used.*

Yields for pasture grasses listed by Russell (1966) are all less than .75 kg/m². The State of Wyoming estimates an average yield density of 0.22 kg/m² for pasture grass (Lyda Hersloff, Rocky Mountain Energy). *A value representative of the West should be used in the GEIS and site-specific values used in evaluating individual applications.*

4. t_v - The duration of exposure assumed in UDAD is 60 days. This value may be appropriate for commercial crops but represents an upper limit for garden vegetables. *A weighted average representing the crops grown in the study area should be used for individual applications. For the GEIS, a weighted average representative of the crops assumed to be grown should be used.*
5. B_{vi} - Soil to plant transfer coefficients are listed in Table G-3.2 of the GEIS. Coefficients are listed for uranium, thorium, radium and lead.
    a. Uranium - Values in the UDAD Code are based on the work of Ng (1968). The value is an average value.
    b. Thorium - The value assumed in the UDAD Code is 4.2×10^{-3} for all plants. No reference could be found for this value. Garten (1978) presents a range of values from 4.5×10^{-5} to

Vegetation Type	Y_v
Leafy Vegetables	1.5
Other Above Ground Vegetables	7.0 E-1
Potatoes	1.8
Root Vegetables	4.0
Strawberries	2.7
Melons	8.3 E-1
Orchard Fruit	1.7
Wheat	3.4 E-1
Corn and Other Grain	3.5 E-1

Table 2.2 Vegetation Yield, Y_v

kg Fresh Weight /m^2

(Adapted from Fletcher and Dotson,(1971), Table III-11)

2×10^{-3}. The UDAD value exceeds the maximum value of this range. *It is recommended that the NRC select a more representative value.*

c. Radium - The UDAD Code value of 2.0×10^{-2} for edible above and below ground vegetables represents the maximum value of the range listed in a report by McDowell-Boyer, et al, (1979). *A more representative value should be selected.* No reference was found for the values for potatoes, feed, or pasture grass.

d. Lead - The UDAD value seems to representative of the range of values presented by McDowell-Boyer.

An alternative approach method for calculating vegetation concentrations has been described by Travis (1979). In a study conducted on radon dispersion and dosimetry, the UDAD Code submodel was compared to one referred to as a "market basket" approach. Market basket estimates of vegetation concentrations were found to be a factor of 10 less than those found using the current UDAD approach. The authors of the study concluded that the market basket estimates were more realistic. *It is recommended that the NRC consider incorporating transfer coefficients based on the market basket approach into the UDAD Code.*

2.3.4 Concentrations in Meat and Milk

Key Parameters include:

1. Q - The feed ingestion rate of livestock is assumed to be 50 kg/day. This value was taken from the Hermes Code. The Hermes Code, however, assumes an 80% moisture content. Ingestion rates at specific sites will depend on local moisture content which is seldom as high as 80% in the Western States. As a result, feed ingestion rates measured in fresh weight are much lower in the Western States, i.e. the State of Wyoming estimates a feed ingestion

rate of 13.6 kg/day, fresh weight (Lyda Hersloff, Rocky Mountain Energy). *Conversion of all Q values to dry weight is recommended in order to eliminate these inconsistencies, caused by vast differences in moisture content, without affecting the total radionuclide content.*

2. .5 - Since most mills are located in arid regions of the west, to assume that 50% of cattle feeding requirements are satisfied by pasture grass is optimistic (Jakubowski, 1979). *A value more representative of site-specific conditions should be developed by surveying the region in question. For the GEIS application values representative of the west should be used.*
3. F_{bi} - No reference was found for the uranium, thorium, and lead transfer coefficients. Source documents should be cited. The value for radium used in the UDAD Code is derived from the report by McDowell-Boyer (1979). The UDAD value, however, is less than the value cited in that report.
4. F_{mi} - 6.1×10^{-4} is the UDAD uranium value recommended by Ng (1977). Garten (1978) lists a range of 4×10^{-5} to 2.7×10^{-4} with a mean of 1.4×10^{-4} based on field studies. *An average value based on Garten's range may be more appropriate.* The thorium value is a maximum value derived by Ng (1977). *A representative value should be used.* The radium value is representative, as is the lead value.

2.4 Dose Calculations for Individuals

Most biological and metabolic values used in dosimetry calculations are taken from the Reference Man (ICRP, 1975). Although subject to variations, the ICRP literature defines Reference Man as being Caucasian between 20 and 30 years of age, weighing 70 kg, and standing 170 cm tall. It is noted however, that Reference Man "...should not be considered as representative for a particular population...". In discussing the concept and purpose of Reference Man, the ICRP emphasizes that "...it remains for the various organizations concerned with control of radiation exposure at the national or regional levels to determine what modifications of Reference Man, if any, may be appropriate for the population at risk." Reference Man must therefore be used as a starting point for biological information rather than an absolute model.

For parameter values relating to dose equivalents, the default values for effective energies absorbed per disintegration (MeV.rem/dis.Rad) listed in the Argonne documentation are taken directly from the International Commission on Radiological Protection Report Number 2 (ICRP 2, 1959) with the exception of Pb-210 values. In this case, only the effective energy listed for lymph nodes was taken from the ICRP report. Values of unknown origin are listed for the three regions of the respiratory tract.

MPC values in ICRP 2 are in the process of being replaced by "Annual Limits of Intake (ALI)" in ICRP 30 (in press). The UDAD Code should be revised to utilize the most recent dose conversion factors available from ICRP.

2.4.1 Inhalation Dose

The only reference cited for the lung submodel of the Code is the Report of ICRP Committee II on Permissible Dose for Internal Radiation (ICRP, 1966) which presents details of the first version of the ICRP's Task Group Lung Model. Subsequent revisions have since been made which have been included in the Code. Constants in Table 8.1 are from ICRP Publication No. 19 (1972). Other revisions have been made based on Health Physics 13:1251 (1967).

Equations for calculating dose rates and dose equivalents from particulate inhalation are consistent with the Task Group Lung Model and recent updates. The major limitation on inhalation dose calculations appears to be inadequate input data as discussed in Section 2.1.3.1. The equations are as sophisticated as can be justified by the use of the generalized translocation parameters given by the Task Group on Lung Dynamics.

The dose conversion factor for inhaled radon progeny is given as 0.625 mrem/year resulting from continuous exposure to one pCi/m^3. This conversion factor is based on several intermediate factors, none of which are known to more than one significant figure. *Since the epidemiological data are expressed in terms of risk per WLM* *exposure, a more satisfactory approach to radon dosimetry and health impact analysis would be to express cumulative exposures in WLM rather than trying to convert to millirems.*

2.4.2 External Doses

A review group sponsored by Oak Ridge National Laboratory (Proceedings, 1978) has stated that the semi-infinite model may overestimate doses at short downwind distances by one or two orders of magnitude.

2.4.3 Ingestion Doses

The modeling techniques and metabolic rates used by UDAD are the most recent and generally recognized means for determining ingestion dosimetry but should be revised as soon as the new data in ICRP 30 are available.

2.5 Dose Calculation for the Regional Population

2.5.1 Annual Population Dose Commitments

As stated by the Oak Ridge review group the population dose committment is a calculation of "...very limited value (Proceedings, 1978)". These calculations, used to compute average exposure values, are based on the same submodels used to calculate individual dose commitments. Additional assumptions are made concerning population growth, ingestion rates, food production rates, etc. A quantitative discussion of the uncertainty and conservatism in these assumptions would be of little value due to the uncertainties inherent in the overall approach and concept. The population dose commitment figure is useful only as a relative index to be used in comparing alternative mill sites and technologies. *The NRC should not represent these dose commitment figures to the public as being accurate in an absolute sense, and must define the assumptions upon which they are based.*

2.6 Annual Environmental Dose Commitments

The environmental dose commitment concept is designed to estimate the irreversible effects of long-lived radioactive pollutants. Calculations are based on the same equations used to calculate individual and population dose and additional assumptions are made. "...Obviously, these numerical estimates of projected impact are subject to considerable uncertainty, this is due both to the variability associated with all projections and the currently indeterminate character of some of the important parameters in the analysis." (United States Environmental Protection Agency, 1974). Environmental dose commitment calculations should be used only to compare alternative mill and tailings disposal configurations.

2.7 Health Effects

The UDAD Code prepared by Argonne does not estimate health effects of mill releases. Health effects calculations for the region within a radius of 80 kilometers of the model mill are presented in Appendix G-7 of the GEIS. These calculations reflect the same inadequacies as those in the BEIR 1972 report from which they are taken. For example the number of premature deaths per lifetime per million man-rem resulting from cancers of different etiologies are simply added as presented in Table G-7.1. Because mortality rates, latent periods, and years of life lost all differ, this is simply an inaccurate compilation and presentation of data. Tables G-7.2 and 3 provide estimates of total premature deaths based on the absolute and the relative risk model respectively. As in the BEIR Report, these tables are misleading because they imply that the relative risk model shows approximately 4 times more loss of life than the absolute risk model. Based on years of life lost, however, rather than total numbers of premature deaths, each of these risk models indicates the same total health risk. *It is inappropriate to average the number of calculated premature cancer deaths based on the absolute and relative risk models while ignoring the age distribution of cancer victims.*

The risk estimates of death due to bone cancer (pages G-60 and G-61) are based on the assumption of a linear non-threshold response curve similar to the other cancer risks. This approach ignores the fact that bone sarcomas have been observed only at mean bone doses above 1160 rads from Ra-226 or at endosteal doses above 760 rads (UNSCEAR, 1977). The most recent data on bone cancers summarized in UNSCEAR 77 suggest that the incidence is proportional to the square of the bone dose. *It would seem more appropriate if health effects calculations used in the GEIS were based on the most recent data available.*

3. MODEL OVERVIEW

The discussions presented in the previous section indicate that many of the UDAD Code submodels are not the best available. A listing of these submodels is presented in Table 3.1. This condition justifies a conclusion that the UDAD Code is not a satisfactory model for estimating the radiological impacts of uranium mills. Another condition which justifies this conclusion is also based on the discussions of the previous section, i.e. the degree of conservatism inherent in many individual submodels results in an unacceptable level of conservatism in UDAD Code dose equivalent estimates.

Due to the uncertainty inherent in model predictions those models which consistently overpredict the danger to the public are acceptable to regulatory agencies. This practice is consistent with agencies' charge to protect the public. Thus the conservative factor inherent in many of the UDAD Code submodels is considered acceptable. However, when the submodels are linked within the framework of the UDAD Code the cumulative effect of these individual factors is that Code dose estimates reflect a compounded conservatism (or overestimate of doses) of unacceptable magnitude.

A summary of UDAD Code submodel conservatisms is presented in Table 3.2. Examples of the cumulative effect of submodel conservatisms are as follows:

- ★ The overestimate of radionuclide air concentrations of a factor of 2 to 15 associated with the Gaussian dispersion submodel, and an overestimate by a factor of 2 to 4 of air concentrations due to the deposition model will cause <u>inhalation</u> dose equivalents at near receptors to be overestimated by a factor of 4 to 60.
- ★ The dispersion submodel overestimate of a factor of 2 to 15, the deposition submodel overestimate of a factor of 2 to 4, and the external dose submodel overestimate of an order of magnitude will cause <u>external</u> dose equivalents at near receptors to be overestimated by a factor of 40 to 600.

Submodel	Parameter	Recommended Replacement
Ore Pad & Grinding Source Terms		More accurately model the size distribution
Yellowcake Drying Source Terms		More accurately model the size distribution
Tailings Pond Particulate Source Terms		Correct application of Travis' (1975) model
	C	Value applicable to tailings pond
	C_v	Value applicable to tailings pond
	Moisture content	10 to 20 %
	Particle Size:	A more accurate representatio of particle size distribution
Air Dispersion	Mixing Height	By stability class
	Building Wake Effects	Several means available to account for
	Complex Terrain	EPA approved terrain modification. Possible use of finite difference or particle-in-cell models
	Dispersion Coefficients	Adjusted Pasquill-Gifford coefficients
	Low Wind Speed Conditions	NRC Power Plant Correction
	Gravitational Settling	Only apply when appropriate
	Deposition Velocities	Hicks' (1976) model
	Dry Deposition	Horsts' (1975) model
Radon Daughter Ingrowth		Further study needed
Ground Concentration	Weathering Half-Life	More reasonable value such 6 months
Concentrations in Vegetation		Replace approach with market basket transfer factors

Table 3.1 UDAD Code Submodels
Suggested Replacements
(continued on next page)

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[1] See text for further detail

Submodel	Parameter	Recommended Replacement[1]
	E_v	More representative value than a maximum
	Y_v	Representative value
	t_v	Representative value
	B_{vi} (Thorium)	Representative value
	B_{vi} (Radium)	Representative value
Concentrations in Meat and Milk	Q	Representative value
	.5	Representative value
	F_{mi} (Uranium)	Representative value
	F_{mi} (Thorium)	Representative value
Inhalation Dose	Radon	Express cumulative exposures in WLM

Table 3.1 UDAD Code Submodels
Suggested Replacements

[1] See text for further detail

Submodel	Parameter	Conservatism[1]
Ore Pad & Grinding Source Terms		Not easily quantified-further study-needed-average size of 5 μm more appropriate than 1 μm
Yellowcake Drying Source Terms		Not easily quantified-further study needed-average size of 5 μm more appropriate than 1 μm
Air Dispersion	Building Wake Effects	Site-Specific effects but enhances dispersion thus reducing concentrations
	Complex Terrain	Site-Specific effects but Gaussian models applied in complex terrain known to overestimate concentrations by factors of 2 to 15
	Low Wind Speed Conditions	Gaussian models overestimate concentrations by up to a factor 8
Plume Depletion	Gravitational Settling	Improperly applied causes enhanced deposition and overestimates of concentrations at near receptors
	Deposition	Source term modification currently used causes concentrations at near receptors to be overestimated by up to a factor of 4
Ground Concentrations	Weathering Half-Life	Current value of 50 years Available data indicate a value on the order of 6 months to one year more reasonable. Factor of 50 too large
Resuspension	10^{-5} and 10^{-9}	Inherent uncertainty of several orders of magnitude - Values chosen specifically to be conservative particularly assuming a value of 10^{-9} forever

Table 3.2 UDAD Code Submodel Conservatisms
(continued on next page)

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[1] See text for greater detail

Submodel	Parameter	Conservatism[1]
Concentrations in Vegetation		Cumulative effect of all parameters estimated to cause concentrations to be overestimated by a factor of 10.
	E_v (Above ground)	Maximum value of 1.0 currently used - More appropriate value would be closer to .1. Factor of 10 difference
	E_v (Below ground)	Current value of .1 - most known values are less than .1
	Y_v (Crops)	Of reported values only two exceed value used - Degree of conservatism depends on crops being considered
	Y_v (Pasture grass)	Current value exceeds published values
	t_v	Assumed value of 60 days is excessive for garden vegetables
	B_{vi} (Thorium)	May be conservative by a factor of 10
	B_{vi} (Radium)	May be conservative by a factor of 2
Concentrations in Meat and Milk	Q	Current value of 50 kg/day is excessively large
	% of diet constituted by pasture grass	Current value of .5 is excessively large
	F_{mi} (Uranium)	Current value of 6.1×10^{-4} may be a factor of 5 too large
	F_{mi} (Thorium)	Maximum value currently used
External Dose		Semi-infinite model may overestimate doses at short downward distances by one or two orders of magnitude

Table 3.2 UDAD Code Submodel Conservatisms

[1] See text for greater detail

an overestimate by a factor of 2 to 4 of air concentrations due to the deposition model will cause inhalation dose equivalents at near receptors to be overestimated by a factor of 4 to 60.

- The dispersion submodel overestimate of a factor of 2 to 15, the deposition submodel overestimate of a factor of 2 to 4, and the external dose submodel overestimate of an order of magnitude will cause external dose equivalents at near receptors to be overestimated by a factor of 40 to 600.
- The dispersion submodel overestimate of a factor of 2 to 15, the deposition submodel overestimate of a factor of 2 to 4, and the possible factor of 10 overestimate of the fraction of deposited material reaching edible portions of plants will cause the portion of vegetable ingestion dose equivalents due to direct deposition from air to be overestimated by a factor of 40. to 600.

These examples illustrate the cumulative effect of only a few of the more easily quantified assumptions of the Code.

In order to quantify the conservatism inherent in UDAD Code predictions due to all of these submodel conservatisms, an extensive analysis would be required. Lacking such an analysis the numbers derived in the simple examples above indicate that UDAD Code predictions overestimate actual dose predictions at near (0 to 5 km) receptors by unacceptable amounts. The same is probably true for far receptors although to a lesser degree. An alternative approach to considering uncertainty would be to determine statistical confidence levels for UDAD Code predictions based on the uncertainties inherent in the submodels. Extensive studies would be required and are recommended. Until such confidence levels are established, *efforts should be made to utilize the most realistic values available for each input parameter, rather than the most conservative value for each.*

4. MODEL APPLICATIONS

4.1 General

The discussions presented in Section Two have cited materials which indicate the uncertainty inherent in the submodels of the UDAD Code. This uncertainty is described in the support documents referenced, and in the GEIS appendices and Argonne publications. Those discussions also exemplify where specific conservative assumptions are made to assure that actual dose equivalents are not underestimated. As was stated in Section Three the level of conservatism inherent in UDAD predictions is unacceptable. However, if the UDAD Code is to be used in its present form as it has been for both the GEIS and individual mill applications, there must be an objection to the way UDAD Code predictions are presented to the public. In both the GEIS and individual environmental statements dose estimates are represented as being absolute predictions; little or no discussion of uncertainty or conservatism is included in either the text or as footnotes to tables and figures. This is not an accurate presentation of the dose equivalent calculations. *Whenever dose equivalent estimates are presented the NRC should enumerate and evaluate the uncertainties and conservatisms involved in computing dose estimates. In addition the NRC should provide a detailed explanation of the state of radiobiological research. This is particularly important when estimates are used in safety and cost benefit analyses.*

4.2 GEIS Application

The UDAD Code, as applied in the GEIS, exhibits many of the uncertainties and conservatisms previously discussed. It is used primarily to calculate individual and population dose commitments for the Base Case and alternative scenarios. Base Case projections are discussed in Chapter 6 and in the summary, where numerical results are presented in prominent graphics and tables without qualifying remarks. Risks are interpolated from the UDAD results and are usually expressed as incidences of premature death.

The Code is also cited in Chapter 9 where dose and dose rates are calculated and used as a basis for examining and evaluating alternative control scenarios. Applications in Chapter 9 include an evaluation of emission controls during and after mill operation. Their cost-benefit discussions of Chapter 11 are in part derived from these absolute projections. Recommendations for required tailings cover depths and other specifications presented in Chapter 12 are based on Code projections.

Where Code predictions are presented in the GEIS there is not sufficient qualifying information included to identify conservatisms for the unfamiliar reader. Worst case examples are used and calculations are presented as absolute results without qualifying statements. Footnotes discuss the uncertainty in health effects calculations only. Discussions of subtle conservative assumptions and uncertainties are scattered throughout the document rather than under one section heading or accompanying graphics. Mention of uncertainties are brief and incomplete. A definitive section specifying the context in which data is to be interpreted is warranted as are explanatory footnotes to tables and figures.

UDAD Code predictions are used throughout the GEIS as basis for health effects calculations. The Code serves as an integral tool in the decision making process. In light of assumptions made in the GEIS and shortcomings previously mentioned, the UDAD Code is used in a way that is not justified. Recommendations for regulatory controls presented in the GEIS should not be accepted.

4.3 Site-Specific

Many of the parameters used in the UDAD Code change according to site-specific conditions. To require that all mill license applicants submit extensive site-specific information useful only in UDAD Code evaluations would be unreasonable.

Many mills are shown to satisfy regulations while using the conservative UDAD default values. *The NRC should continue to run increasingly more site-specific evaluations of each milling application as needed.*

The NRC has published a list of site-specific parameters in the Draft Regulatory Guide/Value Impact Statement, however, this list is incomplete. Additional parameters which have been identified as site-specific during the course of this study are listed in Appendix A.

5. FURTHER RECOMMENDATIONS

To conclude, recommendations for NRC policy and future study are offered:

Until revisions are made the UDAD Code should not be used. This is true both for individual applications and use in the GEIS. If the Code is applied then it should only be used as an information tool. UDAD Code predictions should not be used to determine compliance with regulations or as a basis for developing regulations.

A sensitivity analysis of the UDAD Code should be conducted. Further research is needed to improve the accuracy of many of the submodels. These research needs have been extensively discussed elsewhere (Proceedings, 1978). However, to our knowledge, no priorities for granting research funds have been established. Conducting an extensive sensitivity analysis of the Code would allow critical parameters to be identified. Priorities for further refinement of Code submodels could be established and research funds could then be effectively allocated.

The NRC should continually update and validate these models. In the Draft Value/Impact Statement it is stated that no additional research or technical assistance contract will be needed to support model development. As indicated in previous sections, additional studies are needed.

Appendix A

Site - Specific Parameters

The processes modeled by the UDAD Code are all dependent on site-specific conditions. In applying the Code the NRC assumes values for parameters within the submodels which often do not reflect conditions at a particular site. The following is a list of parameters for which companies applying for licenses should have the option of supplying site-specific values. (This list augments that found in Appendix A of the Draft Regulatory Guide.)

Submodel	Parameter	Description	Comments	Possible Sources of Values
Tailings Source Term	Z_o	Surface Roughness Height	Depends on Surface Conditions	Site Visit
Deposition	V_d	Deposition Velocity	Dependent on Surface Conditions	Site Visit[1] (See Section 2.2.2)
Dispersion	—	Terrain Effects		Topographic Maps
Ground Concentrations	λ_e	Environmental Loss Rate Constant	Dependent on area soil type	Little information currently available except for studies on radionuclides other than the U-238 series such as those by Rogowski and Tamura (1970) and Krieger and Burmann (1969).
Vegetation Concentrations	E_v	Fraction of foliar deposition reaching edible portions of vegetation, V.	Should be representative of crops grown in area.	Values from Hermes based on crop information from the State Dept. of Agriculture or the BLM.
Vegetation Concentrations	P	Areal soil density for surface mixing.		State Dept. of Agriculture, Soil Conservation Service.
	t_v	Assumed duration of exposure for vegetation, V.	Should be representative of crops grown in area.	State Dept. of Agriculture, Soil Conservation Service.
	Y_v	Assumed yield density of vegetation, V.	Should be representative of crops grown in area.	State Dept. of Agriculture, Soil Conservation Service.

Submodel	Parameters	Description	Comments	Possible Sources of Values
Meat Concentrations	Q	Assumed feed ingestion rates.	Must be expressed based on moisture content.	U.S.D.A. - Soil Conservation Service. BLM - Range Management Division State Dept. of Agriculture, Animal Husbandry Local Ranchers
Meat Concentrations	.5	Fraction of the annual feed requirement assumed to be satisfied by pasture grass of locally grown stored feed.		BLM District Office - Range Management Division Local Ranchers
Ingestion Doses	U_{vk}*	Ingestion rate of vegetation V. by an individual in age group K.		U. S. Dept. of Agriculture - Regional Office U. S. Dept. of HEW - Regional Office Local University extension services State Dept. of Health
	U_{bk}	Meat ingestion rate for age group K.		U.S. Dept. of Agriculture Regional Office U.S. Dept. of HEW Regional Office Local university extension services State Dept. of Health
	U_{mk}	Annual milk ingestion rate for age group K		U.S. Dept. of Agriculture Regional Office U.S. Dept. of HEW - Regional Office Local University extension services State Dept. of Health

*Ingestion rates used in UDAD are based on the diet of a "typical" rural farm family in the North Central United States. The diet of families in individual mill regions in the Western United States will be different.

As a general comment, in past UDAD applications the NRC has made conservative assumptions concerning the food source for people living at receptors of concern. For example, people are assumed to have vegetable gardens which produce all their needs, and their milk and beef are assumed to come from pastures in the mill vicinity. Account should be made for actual food production and distribution practices within each particular region.

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Part III

A. Radiological Aspects

4. Perspective on Risk

AN ANALYSIS OF THE RISKS PRESENTED IN THE DRAFT GEIS ON URANIUM MILLING (NUREG-0511) IN PERSPECTIVE TO OTHER RISKS IN SOCIETY

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The draft generic environmental impact statement on uranium milling makes many projections concerning uranium milling activities and resultant health effects for mills expected to be in operation by the year 2000. In this report these predictions are analyzed in relation to other risks present in our society. Derivation from the draft GEIS of various figures used in this report is presented in the appendix hereto.

Perspective on Occupational Risk

The mortality risk to an employee in a uranium ore processing mill is 0.04% per year of employment, or 2% for a 50 year career. This is approximately equal to the risk from accidents only for agricultural workers or for workers in transportation and public utilities[1], and is less than the risks from accidents only by a factor of 1.5 for construction workers (8.5 for demolition workers, 6.2 for those working with prefabricated steel and concrete, and 3.5 for pile drivers and dredgers[2]), 1.7 for miners and quarry workers (2.2 for all coal miners, 2.8 for those working underground, and 4.8 for augur surface miners[2]), 1.9 for travelling salesmen (assuming 50,000 miles of driving per year at the average accident rate), 2.0 for firemen, and 2.1 for loggers (5.8 for loggers involved in felling trees[2]).

But the danger to uranium mill workers is from disease, not just from accidents, so we should consider the risks from disease in other occupations. For black lung disease among coal miners, it is 0.8%/year, or 20 times higher than the risk to uranium mill workers. For asbestos workers it is 2% per year, or 50 times higher, and it is similar for workers involved in the manufacture of benzidine and of B-naphylamine[3].

According to a recent Dept. of HEW study, 20% of all cancer in the U. S. is due to occupational exposure to chemical carcinogens, which means that the lifetime risk to the average worker is 7%. It is widely believed that this estimate is too high, perhaps by a factor of 5-10, but it includes sales and clerical workers, so the risk to those actually exposed to chemicals must be several times higher than the all industries average. Thus, the many millions of people so exposed must have an additive cancer risk of at least 0.05, 2.5 times higher than the risk to uranium mill workers.

There are surely many other diseases brought on by the physical, mental, and emotional demands of the workplace environment that take their toll in shortening our lives. One would think that these have an effect at least comparable to the effects of chemical carcinogens.

Perspective on the long term persistent effects on the public, principally due to radon emission from mill tailings

The long term effects of the 82 mills expected by the year 2000 are to cause about 10 fatalities per year among the 460 million projected population of North America. For purposes of putting risks into perspective, this is equivalent to 4 fatalities per year in the present U. S. population. The number of fatalities per year from some other risks are: all accidents - 100,000; automobile accidents - 50,000; drowning - 8,000; poisons - 4,000; choking on food - 3,000; firearms - 2500; alcohol - 56,000; illicit drugs - 6,000; homicide - 21,000; suicide - 28,000. It is thus abundantly clear that the 4 fatalities per year from uranium mills represent several orders of magnitude less of a danger than many other risks, including some that we pay little attention to. If the mill tailings were covered, the fatality rate would be 250 times smaller still.

Another perspective can be gained by considering the fact that the emissions from uranium mills would reduce future life expectancy by about 15 minutes. Some other actions that reduce life expectancy by 15 minutes are smoking $1\frac{1}{2}$ cigarettes in a lifetime, an overweight person eating 100 extra calories in a lifetime (e.g. one soft drink or one piece of bread and butter), driving an extra half mile per year, crossing a street one extra time every two years, taking one short airplane flight in a lifetime, living in a house without a smoke detector for one month of one's life (less than 20% of U. S. homes have smoke detectors although they cost only about $15), or living downstream from a dam for one week (millions of Americans live their whole lives downstream from a dam).

Moreover, there are many things we can do to increase life expectancy by thousands of times the amount that would be lost due to emissions from uranium mill tailings. General safety improvements over the past decade have reduced accidents enough to increase our life expectancy by 110 days, 10,000 times the toll from mill tailings. An even larger increase of life expectancy, 125 days, is obtained by being serviced by mobile intensive care units, the well equipped ambulances staffed with well trained paramedics which have become available in larger cities over the past five years or so — cities with less then 50,000 population still do not ordinarily have them. Family training in resuscitation would typically add 100 days to our life expectancy, and air bags in automobiles would add 50 days. With all these opportunities not being used, it is difficult to understand worries about the 15 minutes of life expectancy lost due to mill tailings.

The loss of life expectancy for the American public due to other aspects of energy generation and use are: air pollution from burning coal and oil - 14 days, electrocution - 5 days, fires - 2.5 days, asphyxiation by natural gas - 1.5 days, transportation accidents in hauling coal - 1 day, gas explosions - 0.4 days, and dam failures - 0.2 days. By comparison the 15 minutes lost life expectancy from mill tailings is only 0.01 day, tens, hundreds, or thousands of times smaller than each of the above items.

A more global perspective on risks can be obtained from the following list of loss of life expectancy in days due to various risks:

Being unmarried (male)	3500
Cigarette smoking (male)	2250
Heart disease	2100
Being unmarried (female)	1600
Being 30% overweight	1300
Being a coal miner	1100
Cancer	980
20% Overweight	900
<8th Grade education	850
Cigarette smoking (female)	800
Low socioeconomic status	700
Stroke	520
Living in unfavorable state	500
Army in Vietnam	400
Cigar smoking	330
Dangerous job - accidents	300
Pipe smoking	220
Increasing food intake 100 cal/day	210
Motor vehicle accidents	207
Pneumonia - influenza	141
Alcohol (U.S. average)	130
Accidents in home	95
Suicide	95
Diabetes	95
Being murdered (homicide)	90
Legal drug misuse	90
Average job - accidents	74

Drowning	41
Job with radiation exposure	40
Falls	39
Accidents to pedestrians	37
Safest jobs - accidents	30
Fire - burns	27
Generation of energy	24
Illicit drugs (U.S.aver.)	18
Poison (solid, liquid)	17
Suffocation	13
Firearms accidents	11
Natural radiation	8
Medical X-rays	6
Poisonous gases	7
Coffee	6
Oral contraceptives	5
Accidents to pedalcycles	5

Even within the narrow question of health effects of radon, there are much more serious things to worry about. The government is urging us to insulate our buildings to save energy, but this traps radon gas inside for longer than normal times, and hence increases our exposure to radon.[4] If all U. S. homes were insulated to government specifications, the increased annual fatality toll from radon would be over a thousand times higher than that caused by mill tailings wihtout covers, and a half million times higher than from covered mill tailings.

Qualifications on 200 fatalities per GWe-year expected from uranium mill tailings if effects are integrated over hundreds of thousands of years

1. Eventually the mined uranium will probably be used in breeder reactors which increases the energy obtained from it by a factor of 50. Thus there would eventually be only 4 fatalities per GWe-year.

2. All estimates are based on the assumption that there will not be a cure for lung cancer. If there is such a cure in 100 years the effects would be reduced by a factor of 1100, and if the cure comes in 1000 years the effects are reduced by a factor of 110.

About 70% of radon-induced lung cancers are a type called "small cell undifferentiated," and there has recently been good success in treating this type by chemotherapy with cytoxin, vincristin, and adriamycin.

3. If tailings piles are covered, effects are reduced by a factor of 250. Thus there would be 0.8 eventual fatalities per GWe-year if the uranium is used only in LWRs, and 0.016 fatalities per GWe-year if it is used in breeder reactors.

Perspective on $370,000 per health effect averted if tailings piles are covered and effects are integrated over 100 years

Many of the health effects considered are non-fatal, so the cost per fatality averted is about $600,000. There are many ways in which Society can save lives at a cost much lower than $600,000 per fatality averted.[5] Cancer screening programs for cervical and colorectal cancer cost less than $40,000 per life saved, and screening for lung and breast cancer cost less than $100,000. There are multiple screening programs in industry which are saving a life for every $30,000 spent but these have not been widely implemented. Putting mobile intensive care units in smaller cities than now have them would cost $30,000 per fatality averted. Hypertension screening and control programs could save lives at costs of about $75,000 each.

There are many highway safety measures that could avert fatalities at an average cost below $50,000. Some estimates of costs per fatality averted from the National Highway Safety Needs Report are: regulatory and warning signs - $34,000; guard rail improvements - $34,000; skid resistance - $42,000; bridge rails and parapets - $46,000; wrong way entry avoidance - $50,000; impact absorbing roadside devices - $108,000; breakaway signs and lighting posts - $116,000; it also lists several other measures with costs below $300,000.

Driver education in high schools, which saves a life for every $90,000 spent (including payment for the students' time), is not being instituted in some areas and is being discontinued in others because it is too costly.

Air bags in automobiles cost about $300,000 per fatality averted, and there are even more cost-effective passive restraints available to protect people in automobiles.

Life saving measures in foreign countries can be very cheap. An immunization program in Indonesia could save 300,000 lives at a cost of $100 per fatality averted. Food for overseas relief in countries like India would cost only $5,000 per life saved.

Smoke detectors in homes save a life for every $60,000 spent, including a generous allowance for installation and maintenance, but less than 20% of American homes have them. There are undoubtedly many other safety devices and health protection measures that could be incorporated in homes and other buildings that would save lives at a cost well below the $600,000 per life saved by covering mill tailings.

Qualifications on $500 per fatality averted if tailings piles are covered and if effects are integrated over hundreds of thousands of years

1. This is based on the assumption of no cure for lung cancer over this time period. We have pointed out above that there is already good progress on curing the principal types of lung cancer caused by radon.

2. This ignores the fact that money spent now to save lives in the distant future could be invested to draw interest which would make much more money available to save lives at that future date. One dollar invested now at even 1% annual real interest (i.e. discounting inflation) becomes $20,000 after 1000 years, $400 million after 2000 years, and $8 trillion after 3000 years. At 5% interest, which is probably more realistic, these times are reduced five-fold. As long as money can draw real interest and money can be used to save lives in the distant future, it would be much better to set up even a small trust fund for future life saving.

If one questions the ability of capital to continue to draw real interest far into the future, there are more subtle ways in which we can invest money for the benefit of our progeny even more effectively. For example, money invested in research now benefits all future generations, paying a high rate of compound interest if we can judge by past performance. The high standard of living we enjoy today is largely the product of small amounts of money and effort invested in research over the past two centuries.

3. Society does <u>not</u> value future lives equivalently with lives of those now living. For example, with such a philosophy we would spend much more money on medical research rather than on medical care, but we actually spend much more on medical care. Even our research expenditures are targeted at

short term pay-offs. Congress was willing to spend vast sums on cancer research when it believed that it would develop a cure for cancer in our lifetime. If it were informed that the cure would not come for hundreds of years, the money would all but dry up, although the number of lives eventually saved would be virtually the same.

Validity of applying extremely small calculated risk-per-individual estimators to very large populations

1. If the small risk per individual were accurately known, I believe that the procedure would be just as valid if the risk-per-individual is 0.000001 as in the present context as if it were 0.001. When probabilities approach unity, attitudes change. For example, Society is willing to spend much more per life saved for kidney dialysis machines or iron lungs where a single identified individual is at a risk approaching unity without such a device.

There is a wide general acceptance of the procedure of applying small risk-per-individual estimators to large populations. It is used by many national and international agencies and by scientific commissions. It is used frequently in the scientific literature and in public health decision-making.

2. Since the extremely small risk per individual in the present context is from radiation, one might question the validity of the linearity hypothesis on which the estimates are based. There is significant activity in the scientific community on this question, and the experts are roughly evenly split on whether or not this procedure over-estimates effects of small doses. However, most of this controversy centers on gamma rays and X-rays.("low LET radiation"), and there is a substantial majority favoring linearity for alpha

particles which are the principal radiation from the uranium industry.

However, there is a paper[6] soon to appear in the journal "Health Physics" which offers extensive evidence that current estimates of effects of low level radon exposure, which are based on the linearity hypothesis, are grossly exaggerated. If this evidence is accepted, current estimates would be reduced by an order of magnitude.

Appendix: Review of risks as assessed in GEIS

A model mill produces 920 MT/year of U_3O_8, enough to provide fuel for about five 1000 MWe LWR nuclear power plants. Projections are based on 82 mills by the year 2000, with operation of 880 mill-years (=4400 GWe-yr) by that time.

Occupational mortality risk to a person who works in a mill for 50 years is 2%. The total number of occupation-caused fatalities among mill workers due to exposure between 1978-2000 (88,000 mill worker-years) is 37(+10 genetic defects among their progeny). This represents about 0.01 fatalities/GWe-yr of electricity production.

Among the North American public, from 82 mills there would be a long term persistent fatality rate largely due to radon emissions from mill tailings, of 9.8/year (+2.0 genetic defects/yr). This is about 0.0017 fatalities/yr per GWe-yr. Integrated to infinity (i.e. over the 77,000 year half-life of ^{230}Th) this is 200 eventual fatalities/GWe-yr. With the specified covering of tailings piles, the persistent mortality rate would be 0.04/year, causing 0.8 eventual fatalities/GWe-yr. The cost of covering tailings piles is not more than 30¢/lb-U or $100,000/GWe-yr. If the persistent fatality rate from radon emission is integrated over 100 years, this is $600,000/fatality averted; if it is integrated to infinity, it is $500 per eventual fatality averted. The GEIS gives these last two figures as $370,000 and $370 per "health effect" averted.

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Part III

A. Radiological Aspects

5. Need for Cost Effective Analysis

EVALUATION OF LONG-TERM RISK TO THE GENERAL PUBLIC FROM TAILINGS RADON EMANATION AND THE COST-EFFECTIVENESS OF PROPOSED CONTROL MEASURES

Prepared as Part of
the Comments by the American Mining
Congress, Uranium Environmental
Subcommittee

in connection with

The Nuclear Regulatory Hearing
NUREG-0511

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INTRODUCTION

The Draft GEIS Approach

One of the most important considerations addressed in the draft GEIS is the provision of adequate protection to the public from the long-term effects of radon emanation from the mill tailings. The existence of possible risks far into the future adds another dimension to the already complex problem of evaluating the costs and benefits or the application of ALARA to alternative control measures.

The staff struggled with the admittedly complex problem of selecting appropriate controls as follows:(1)

> "The staff considered but decided it would not be reasonable to attempt making a fully monetized or quantified balancing of costs and benefits in recommending the proposed limits on radon attenuation which is a very long-term problem."

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(1) Section 12.3.3.6

"*The staff chose not to invoke such rigorous cost-benefit balancing because*, while it appears to offer a "*rational*" approach to standard setting and avoid arbitrariness, *it is inevitable that arbitrary judgments and assumptions must still be made*. This is particularly true in the case of radon from tailings because of the *uncertainties associated with the very long-term nature of the hazard*. Furthermore, such a cost-benefit approach would constitute an oversimplification of the tailings disposal problem, which invoves many interrelated aspects,and as such would be misleading." (Emphasis added)

"*Factors which will ultimately determine how may real effects will occur*, and on which there is *large uncertainty*, include such things as: *future population sizes and distribution*, impacts of *changes in climate* (such as heating of the earth's surface and atmosphere, the greenhouse effect), *scientific advances (which might include a cure for cancer*)*, and long-term performance of tailings. *These uncertainties compound those existing in computational models used in estimating costs and effects*.

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*If such an event occured, and recent medical history suggests a high probability that it will occur in the foreseeable future, the problem of long-term health effects from cancer is virtually moot."

"This range of uncertainty illustrates the problems which would be encountered in attempting to utilize predetermined, fixed cost-benefit criteria in establishing an appropriate level of radon control. . . . The range presented in the table reflects only the uncertainty which exists in computational models. Uncertainties concerning future events, such as erosion or climatic influences as discussed above would exacerbate the problem of applying a specific cost-benefit criteria." (Emphasis added)

"Furthermore, when weighing committed long-term impacts against costs to control them, the period of time over which the impacts will be taken into account must be selected: should it be 100, 1000, 100,000 or 1,000,000 years? Obviously, by arbitrarily selecting different time periods, almost any amount of money for control of radon could be "justified." (Emphasis added)

"Finally, there is the intractable problem of deciding how much averting a health effect ("life" or "life shortening" in the case of a premature cancer death) is worth in monetary terms, that is, of deciding what the cost-benefit decision criteria should be. It would be difficult to decide the worth of health effects today and more difficult to decide the value of future effects (that is, 100, 100,000 years and beyond). Does a premature loss of life 100,000 years into the future have the same value as a life today?" (Emphasis added.)

"In view of this, the staff has weighed alternative radon control levels in terms of how they would meet the simple objective of returning disposal sites to conditions which are reasonably near those of surrounding environment. In conjunction with the proposed limit on radon flux, a conservative approach is proposed with regards to the general mode of disposal. Below grade burial is identified as the prime disposal mode to assure that the effects of natural weathering and erosion processes which could disrupt the tailings isolation are eliminated or reduced to very low levels (Section12.3.2). A minimum thickness is also proposed to provide a measure of conservatism with regards to long-term stability of tailings cover." (Emphasis added) .

In essence, the NRC has identified uncertainties in the computational model used to estimate present health effects, extreme uncertainties in estimating future geomorphic changes and the future course of human endeavors, the specific questions of how far in the future to consider health effects and the "intractable problem of how to assess the 'value' of a health effect averted and rationalized that a rigorous cost-benefit analysis cannot be made. In its place a completely arbitrary ". . ."simple objective of. . . returning disposal sites to conditions which are reasonably near those of the surrounding environment" has been selected as the basis for control.

In addition, conservative requirements of below ground disposal and a minimal thickness of cover have also been set arbitrarily without justification beyond the staff opinion that they are appropriate. As another result of these arbitrary choices, the discussion of "alternatives" in Sections 8, 9, and 11 in the GEIS is not a discussion of the effectiveness and costs of alternative levels of control but of alternatives to achieve the single, arbitrary fixed level of control selected a priori by the staff.

The question of the "reasonableness" of the overall costs of control has received similar arbitrary treatment. Throughout the draft GEIS the rationale has been used that the cost of yellowcake represents only about 10% of the cost of production of electricity. Any costs which represent only a small percent of the cost of yellowcake are, by definition, "reasonable." For example from Section 12.3.2.2, page 12-6:

> "These costs are still considered to be reasonable because they represent a very small fraction of the price of product or the cost of producing electricity." (Emphasis added)

This reasoning is seriously flawed. A small incremental cost per kilowatt multiplied by a very large number of kilowatts can be a large absolute dollar burden on society. As an example, using the 2.5¢/kwh cost of electricity given on page 12-4 of the GEIS, a 1% increase in the yellowcake price and the corresponding increase of 0.1% in the cost of electricity adds a total of about $650,000,000 or an average of $33,000,000 per year to electrical bills for the 20-year period between 1981-2000.(1) If the higher cost approaches for tailings disposal such as Alternative 5 with a specially excavated pit are required, and the GEIS costs are low by an average factor of 2 as discussed elsewhere in the AMC response, the price increase in yellowcake will be closer to 3%. This would triple the previous values to about $100,000,000 per year or two billion dollars over the 20-year period. Either of these estimates is a great deal of money to spend on the basis that it can be passed on to the public hidden in their much larger electric bills. Each increment of expenditure should be justified by the result of a worthwhile increment in risk reduction not because it is small relative to some much larger number.

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(1) Based on the amounts of nuclear power generated each year given in Table 3.2, page 3-2 of the GEIS.

The AMC Alternative

The AMC believes that a GEIS is a good and appropriate vehicle to ascertain the need and the reasonableness of the policies stated by the NRC but many changes are needed in the draft GEIS to accomplish this objective. First, it is suggested that the analysis be divided clearly into two stages in the manner suggested by a recent report from the Presidential Office of Science and Technology Policy.(1) Stage I involves the assembly of the best, middle-of-the road <u>technical</u> information available. This includes risk analyses. Stage II involves the socio-political decision-making and policy development based on the technical information.

Second, while we agree that a rigourous cost-benefit analysis of proposed regulatory changes is difficult, it is possible and essential to informed decision-making. As an example, we have selected the subject of control of radon emanation from tailings disposal areas and have looked at risks and costs in more detail, particularly in terms of incremental risk and incremental costs to avert risk. Regional (near-field) and far-field risks are considered separately. Both values of risk and cost presented by the staff and values believed to be more representative of conditions that would be really encountered are considered.

In the societal decision area levels of risk in the workplace and to the general public that society is now accepting and the levels which appear to be unacceptable are described. Also the amount of money to avert health effects that society is spending and the rationale that experts in the field and several governmental agencies have suggested should be used to judge what should be spent are provided. There is a wide divergence but a surprising amount of agreement among a majority of recommendations to a range that is no larger than the uncertainties in several other parts of the analysis.

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(1) Identification, Characterization, and Control of Potential Human Carcinogens, A Framework for Decision-Making, Office of Science and Technology Policy, Executive Office of the President, February 1, 1979.

This information is presented with the intent of more clearly defining the choices and putting them in better perspective in the manner described recently by the former EPA Administrator, William D. Ruckelhaus.(1)

> "The public, aided by credible scientific data, needs to fully understand what levels of health protection they are buying for what costs-both economic and social," he said. "It may be the public will decide that zero health risk is worth the costs. If the alternatives and their costs are clearly displayed to the public, then through their representatives they can choose."

> "Without a strong effort by EPA to inform it is unlikely the public will understand their choices. The result could be environmental overkill or an unwarranted reaction leading to a reversion to the more smog-filled days of the past. Neither result need occur if choices are more clearly displayed to the public."

In the final analysis, society, through its electric bills, will pay for the risk control measures mandated by the NRC. Society has the right to know if its money is being spent in a prudent and effective manner on solutions to problems that are truly significant to its health and well-being. It is in everyone's best interest to make the best decision possible. This discussion is present in the spirit of developing a fully informed decision.

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(1) Aspen Conference on Future Urban Transportation as reported in "Environmental Health Letter, July 1, 1979

GENERAL ANALYSIS OF RISK

Introduction

Changing societal attitudes in the last ten years have brought forth extensive legislation and a resulting massive regulatory structure to protect the worker and the general public from a great variety of risks, real and imagined, to which they are exposed. This legislation is replete with such vague phrases as "unreasonable risk", "best available technology", "maximum extent reasonably feasible", and "as low as reasonably achievable."

The problem is complicated by differing statutory requirements so that what may be "reasonable" under one law is not under another.

The present state of internal confusion that has resulted is well described in the two literature references that follow:

> "THE BOTTOM LINE IN HAZARD MANAGEMENT is usually some variant of the question, "How safe is safe enough?" It takes such forms as: "Do we need additional containment shells around our nuclear power plants?" "Is the carcinogenicity of saccharin sufficiently low to allow its use?" "Should schools with asbestos ceilings be closed?" Lack of adequate answers to such questions has bedeviled hazard management.
>
> Of late, many hazard management decisions are simply not being made - in part because of vague legislative mandates and cumbersome legal proceedings, in part because there are no clear criteria on the basis of which to decide. As a result, the nuclear industry has ground to a halt while utilities wait to see if the building of new plants will be feasible, the Consumer Product Safety Commission has invested millions of dollars in producing a few puny standards, observers wonder whether the new Toxic Substances Control Act can be implemented, and the Food and Drug Administration is

unable to resolve the competing claims that it is taking undue risks and that it is stifling innovation.

The decisions that are made are often inconsistent. Our legal statutes are less tolerant of carcinogens in the food we eat than of those in the water we drink or in the air we breathe. In the United Kingdom, 2,500 times as much money per life saved is spent on safety measures in the pharmaceutical industry as in agriculture. *U.S. society is apparently willing to spend about $140,000 in highway construction to save one life and $5 million to save a person from death due to radiation exposure*."(1) (Emphasis added)

In the last year the government has recognized the very large problems presented to the country by the myriad of frequently overlapping and often conflicting regulatory activity and has taken steps to introduce some coordination. One important development is the institution of the Interagency

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(1) "Weighing the Risks," B. Fischhoff, P. Slovic, S. Lichtenstein, *Environment*, Vol. 21, No. 4, May 1979, p. 17.

Regulatory Liason Group and the development of common approaches. Another important move is the institution of several studies on common problems one of which includes in its protocol an examination of what is "reasonable risk." Unfortunately, results are not expected to be available for nearly two years so they will not be available for this rulemaking.

Since broadly based policy guidance is lacking on acceptable risk, this section will present extensive information from the literature on occupational and general public risks as they exist today. This technical information will be used as a basis for suggestions of appropriate policy for societal decisions.

Technical Considerations

Two references, Wilson(1) and Cohen(2) have been selected from the voluminous literature on risk to serve as the basic sources for this discussion. Both are recent and comprehensive. Copies have been provided as Attachments 1 and 2.

Tables I through IV list a wide variety of occupational and general risks taken from the Wilson(1) reference. It should be noted that the risks are expressed as deaths/million/year (d/M/y) to facilitate easy comparison, instead of the exponential notation used by Wilson. It should also be noted that estimates of this type often require assumptions and professional judgment in their calculation so that some differences between authors result. (See Wilson, p. 68 and p. 94.) Since the intent here is to examine only ranges and orders of magnitude, moderate differences between sources do not present a serious problem.

Occupational risks are shown in Table I. The values are annual risks averaged over a lifetime of exposure and are arranged in the order of decreasing risk.

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(1) Direct Testimony presented on OSHA Docket No. H-090, Proposed Regulations of Toxic Substances Posing a Potential Occupational Carcinogenic Risk, Dr. Richard Wilson, 1978.

(2) "A Catalogue of Risks," B. L. Cohen, I.S. Lee, <u>Health Physics</u>, Vol. 36, June 1979, p. 701-722.

The highest risks tabulated occur in railroad accidents (excluding grade crossings). These risks are on the order of thirteen hundred deaths per million persons exposed per year. The remaining occupations listed have much lower risks from 800 per million down to a low of slightly less than 100 per million in the manufacturing and service industries. The risks given in Table 1 differ slightly but not substantively from the range of 30 to 12,440 per million per year given for occupational risks in Table 6.23, page 6-45 of the draft GEIS.

Table II lists risks in sports and in recreation. The risks here range from a high of 1800 in a million for motorcycle racing to a low of 10 per million for fishing and bicycling. There is considerable overlap with the occupational range although the activities with large public participation tend to be in the 10-30 per million per year range.

Tables III and IV list commonplace, non-cancerous and cancerous risks in daily life. For the non-cancer risks (Table III), motor vehicle accidents, the effects of alcohol, air pollution, and frequent air travel overlap the lower end of the occupational range, i.e. 100-220 per million per year. The commonplace occurences of daily living such as falls, home accidents, choking, poisioning, electrocution, and occasional air travel fall in a range that is one to two orders of magnitude lower, ~3-80 per million per year. The risks for natural occurrences such as tornados, hurricanes, and lightening are another factor of 10 lower at approximately 0.5 per million.

The corresponding cancer risks (Table IV), largely tend to group approximately around a level of 10 per million which is in the lower end of the range for home accidents just described. Examples include the natural background radiation at sea level, 15 per million; the total risk of living in Denver, 30 per million; being a frequent airline passenger, 15 per million; average U.S. diagnostic X-rays, 10 per million; and a person in a room with a smoker, 10 per million. The ranges of risks just described are summarized in Table V. These ranges will be used for subsequent comparison with risks from uranium milling.

The ranges of risks just described are summarized in Table V. These ranges will be used for subsequent comparison with risks from uranium milling.

The other reference cited (Cohen) expresses risk in terms of the days of life expectancy lost rather than in terms of fatality rates. The objective is to provide a comparison which is more understandable to the public.

A wide variety of risks developed by Cohen are summarized in Table VI. The highest end of the range 1000-3500 days includes such things as marital status (unmarried), smoking, and overweight. Low socio-economic status, living in an unfavorable state, pneumonia, and alcohol (U.S. average) are in the 100-1000 group. A great variety of accidents both in the home and on the job give risks in the 10-100 day range. Finally, diet drinks, coffee, medical x-rays, natural radiation, and natural catastrophies are at the low end with risks of 1-10 days. It is interesting to note that risks from reactor accidents and radiation from the nuclear industry are shown as 0.02-2 days, depending on the source of the estimate used.

TABLE I(1)

CURRENT OCCUPATIONAL RISKS

Occupation	Number of Fatalities (in 1975 unless stated)	Risk/Year (d/M/y)(2)
Railroad Worker (1974) - all accidents excl. grade crossings	688	1300
Firefighters (1971-72 average)	--	800
Agriculture (total)	2100	600
Trade	1200	600
Transportation and utilities	1600	330
Airline pilot	--	300
Steel worker (accident only - 1969-1971)	66	280
Agriculture (tractor driver, 1 driver/tractor)	--	130
Government	--	110
Truck driver (1 driver/truck)	400	100
Jet flying consultant and professor	--	100
Service	1800	90
Manufacturing	1500	80

Source: Accident Facts, 1976 Edition, p. 23, 87.
National Safety Council, 44 N.Michigan Ave., Chicago, IL 60611
Also, (rail worker, steel worker)
W. Baldewicz, et al UCLA-ENG-7485 Nov. 1974)
Airline pilot - see appendix (Wilson Testimony)
Statistical abstract of the U.S., 1976 Ed. Table 1200

(1) Adapted from Richard Wilson, direct testimony presented on OSHA Docket No. H-090, Proposed Regulations for Identification, Classification, and Regulation of Toxic Substances Posing a Potential Occupational Carcinogenic Risk.

(2) Deaths/million/year. Annual risk averaged over a lifetime of exposure.

TABLE II(1)
RISKS IN SPORTS

Sport	Deaths 1975	Risk/Year (d/M/y)(2)
(Averaged Over Participants)		
Motorcycle racing	-	1800
Horse racing	-	1300
Automobile racing	-	1200
Power boating	-	170
Football	-	40
(Based on 40 hours/year engaged in sport.)		
Rock climbing (U.S.)	-	1000
Canoeing	-	400
Skiing	-	30
Boxing (amateur)	-	20
Drowning (all recreation caused, U.S.)	4110	19
Bicyling (assuming 1 person/bicycle)	1000	10
Fishing (drowning, averaged over licenses)	343	10

Source: B. G. Ferris, New Eng. J. Med., 268, 430 (1963).
F. D. Sowby, Health Phys., 11, 879 (1965).
C. Starr, Science, 165, 1232 (1969).
K. S. Clarke, J. Am. Med. Assoc., 197, 894 (1966).
Statistical Bulletin, Metropolitan Life Insurance Co., May 1977.
Accident Facts, 1976 edition.
Statistical Abstract of the U.S.

(1) Adapted from Richard Wilson, direct testimony presented on OSHA Docket No. H-090, Proposed Regulations for Identification, Classification, and Regulation of Toxic Substances Posing a Potential Occupational Carcinogenic Risk.

(2) Deaths/million/year. Annual risk averaged over a lifetime of exposure.

TABLE III(1)

COMMONPLACE RISKS OF DAILY LIFE
(Non-Cancerous Risks)

Source of Risk	Deaths 1974	Risk/Year (d/M/y)(2)
Motor Vehicle (total, 1975)	46,000	220
Alcohol - cirrhosis of the liver	-	160
Air pollution (total U.S.) estimate (sulphates)	30,000	150
Air travel (jet flying professor)	-	100
Falls	16,399	77
Living for one year downstream of a dam (calculated)	-	50
Alcohol - cirrhosis of the liver (moderate drinker)	-	40
Pedestrian auto accidents	8,600	40
Inhalation and ingestion of objects	2,991	14
Home accidents (1975)	25,500	12
Accidental poisoning - gases and vapors	1,518	7
- solids and liquids	1,274	6
Electrocution	1,157	5
Vaccination for smallpox (per occasion)	-	3
Air travel - one transcontinental trip/year	-	3
Tornados - Averaged over several years		0.5
Hurricanes - Averaged over several years		0.4
Lightning - Averaged over several years		0.4

Sources: Accident Facts, 1976 Edition.
Statistical Abstract of the U.S.
Alcohol--detailed discussion in appendix. (Wilson Testimony)
Air travel -- detailed discussion in appendix. (Wilson Testimony)
Air pollution -- detailed discussion in appendix.
Dam failure -- UCLA report, UCLA-ENG-7423, Payyaswamy, et. al., March 1974.

(1) Adapted from Richard Wilson, direct testimony presented on OSHA Docket No. H-090, Proposed Regulations for Identification, Classification, and Regulation of Toxic Substances Posing a Potential Occupational Carcinogenic Risk.

(2) Deaths/million/year. Annual risk averaged over a lifetime of exposure.

TABLE IV(1)

COMMONPLACE RISKS OF DAILY LIFE
(Cancer Risks)

Source of Risk	Risk/Year (d/M/y)(2)
Cosmic Ray Risk	
Airline pilot 50 hrs./mo. @ 35,000 feet	50
Frequent airline passenger	15
Living in Denver compared to N.Y.	10
One summer (4 months) camping at 15,000 feet	10
One transcontinental flight/year	0.5
Other Radiation Risks	
Air pollution (benzo α pyrene, urban U.S.)	30
Natural background at sea level	15
Average U.S. diagnostic medical x-rays	10
Increase in risk from living in a brick building (with radioactive bricks) compared to wood	5
Eating and Drinking	
Alcohol - averaged over smokers and non-smokers	50
Four tablespoons peanut butter/day (aflatoxin)	40
Alcohol - light drinker (1 beer/day)	20
One pint milk per day (aflatoxin)	10
One diet soda/day (saccharin)	10
Average U.S. saccharin consumption	2
Miami or New Orleans drinking water	1.2
1/2 lb. charcoal broiled steak once a week (cancer risk only; heart attack, etc. additional)	0.4
Tobacco	
Smoker, all effects (including heart disease)	3000
Smoker, cancer only	1200
Person in room with smoker	10
Miscellaneous	
Taking contraceptive pills regularly	20

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(1) Adapted from Richard Wilson, direct testimony presented on OSHA Docket No. H-090, Proposed Regulations for Identification, Classification, and Regulation of Toxic Substances Posing a Potential Occupational Carcinogenic Risk.

(2) Deaths/million/year. Annual risk averaged over a lifetime of exposure.

TABLE V(1)

SUMMARY - PRESENT DAY SOCIETAL RISKS

Source of Risk	Risk/Year (d/M/y)(2)
Occupational (See Table I)	
Highest risks	1300 - 8000
Intermediate risks	100 - 800
Lowest risk	80
Sports and Recreation (See Table II)	
Highest risks (Racing and limited participation activities)	1000 - 1800
Intermediate risks (Canoeing, boating)	170 - 400
Lowest risks (General wide participation)	10 - 40
Commonplace Daily Life (See Table III)	
Non-cancer Producing	
Highest risks (Motor vehicle, alcohol, air pollution, frequent air travel)	100 - 220
Intermediate risks (General daily living accidents)	3 - 77
Lowest risks (Natural phenomenon)	0.4 - 0.5
Cancer Producing (See Table IV)	
Smoking (Cancer effect only)	1200
Alcohol	20 - 50
Eating and drinking (Except alcohol)	1.2 - 50
Naturally occurring radioactivity	0.5 - 15
Miscellaneous reference items	
Average annual diagnostic x-rays	10
Person in room with a smoker	10
Regular use of contraceptive pills	20

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(1) Adapted from Richard Wilson, direct testimony presented on OSHA Docket No. H-090, Proposed Regulations for Identification, Classification, and Regulation of Toxic Substances Posing a Potential Occupational Carcinogenic Risk.

(2) Deaths/million/year. Annual risk averaged over a lifetime of exposure.

TABLE VI

LOSS OF LIFE EXPECTANCY DUE TO VARIOUS CAUSES

Cause	Days
Being unmarried - male	3500
Cigarette smoking - male	2250
Heart disease	2100
Being unmarried - female	1600
Being 30% overweight	1300
Being a coal miner	1100
Cancer	980
20% Overweight	900
<8th Grade education	850
Cigarette smoking - female	800
Low socioeconomic status	700
Stroke	520
Living in unfavorable state	500
Army in Vietnam	400
Cigar smoking	330
Dangerous job - accidents	300
Pipe smoking	220
Increasing food intake 100 cal/day	210
Motor vehicle accidents	207
Pneumonia - influenza	141
Alcohol (U.S. average)	130
Accidents in home	95
Suicide	95
Diabetes	95
Being murdered (homicide)	90
Legal drug misuse	90
Average job - accidents	74
Drowning	41
Job with radiation exposure	40
Falls	39
Accidents to pedestrians	37
Safest jobs - accidents	30
Fire - burns	27
Generation of energy	24
Illicit drugs (U.S. average)	18
Poison (solid, liquid)	17
Suffocation	13
Firearms accidents	11
Natural radiation (BEIR)	8
Medical X-rays	6
Poisonous gases	7
Coffee	6
Oral contraceptives	5
Accidents to pedacycles	5
All catastrophes combined	3.5
Diet drinks	2
Reactor accidents - UCS	2*
Reactor accidents - Rasmussen	0.02*
Radiation from nuclear industry	0.02*
PAP test	-4
Smoke alarm in home	-10
Air bags in car	-50
Mobile coronary care units	-125
Safety improvements 1966-76	-110

*These items assume that all U.S. power is nuclear. UCS is Union of Concerned Scientists, the most prominent group of nuclear critics.

Source: "A Catalogue of Risks," B. L. Cohen, I.S. Lee, Health Physics, Vol. 36, June 1979, p. 701-722.

Societal Considerations

Risk and risk decisions are an inherent fact of life and cannot be avoided. This is stated quite succinctly by Pouchin:(1)

> "In whatever we do and in whatever we refrain from doing, we are accepting risk. Some risks are obvious, some are unsuspected and some we conceal from ourselves. But risks are universally accepted, whether willingly or unwillingly, whether consciously or not."

Further, the resources which are available for society to fulfill its overall needs are limited. Thus, the resources that can be expended to reduce risk are also limited.

Therefore, society is facing a problem of the allocation of existing, limited, resources and <u>informed</u>, <u>rational</u> decisions need to be made. The simplistic approach of spending virtually unlimited amounts of money to try to reduce a few, largely randomly selected, risks to zero is not only futile but also is very likely to be counter-productive. We must bring order to our decision-making processes.

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(1) "The Acceptance of Risk," E. E. Pouchin, <u>British Medical Bulletin</u>, Vol. 31, No. 3, 1975.

Voluntary vs Involuntary Risks

The classic work in this area is that of Starr(1) who studied eight activities in terms of voluntary and involuntary risk. One of his key conclusions was that the public is willing to accept risks from voluntary activities, such as skiing, roughly a thousand times greater than from involuntary activities such as food preservatives. More recently Fischhoff, et el(2), have extended the study to 25 activities and analyzed the results directly in terms of annual number of deaths and corresponding benefits. One of their most relevant results, summarized below, shows that the ratio of voluntary risk to involuntary risk is substantially less than 1000 and varies quite strongly with severity of the risk expressed as total annual deaths

Benefits ($Billion/year)	Risk (Annual Deaths)		Ratio
	Vol. Actions	Invol. Actions	Vol./Invol.
0.4	10	10	1
1	60	30	2
10	6,500	550	12
100	600,000	10,000	60

In order to apply the ratio to estimate involuntary risk it is necessary to define acceptable risk levels in voluntary actions in activities that are well known to be hazardous and are engaged in by the general public or by a substantial number of participants. Some examples are shown in the following summary taken from Table II or from Cohen.(3) Sports for basically full time professionals are not included.

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(1) C. Starr, "Benefit-cost studies in sociotechnical systems," in Committee on Public Engineering Policy, Perspective on Benefit Risk Decison Making, National Academy of Engineering, Washington, D.C., 1972.

(2) B. Fischhoff, D. Slovic, S. Lichtenstein, S. Read, and B. Comb, "How Safe is Safe Encough?", Policy Sciences 8, (1978), 127-152.

(3) "A Catalogue of Risks," B. L. Cohen, I.S. Lee, Health Physics, Vol. 36, June 1979, p. 701-722.

Activity	Participants	Deaths per Year	d/M/y
Rock climbing	-	-	1,000
Canoeing	-	-	400
Stock car racing	26,000	10.2	392
Motorcycle racing (Amateur	115,000	22	191
Snowmobile racing	15,000	2	133
Automobile drag racing	145,000	7.4	51
Go-cart racing	18,000	0.6	33
Skiing	-	-	30
Drowning	-	4,110	19
Bicycling	-	1,000	10

At the low end of the scale, at 1000 deaths per year (bicycling), the voluntary/involuntary ratio is about 6 so the calculated acceptable involuntary risk is about 2 d/M/y. For drowning, the ratio is approximately 10 so the involuntary result is about the same, i.e., 2 d/M/y. For the five activities with annual deaths in the range of ∿1 to 20, the ratio varies from 1-2. Calculated acceptable risks are roughly 30-200 d/M/y, which appear to be on the high side compared with most other involuntary risks. Application of the less well defined constant factor of 1000 given by Starr gives a range of 0.01 to 1 d/M/y.

It is suggested that a reasonable value for acceptable levels for involuntary risk by this reasoning is a range of 0.1 to 1 d/M/y. This is the same order of magnitude as the risk from natural disasters and 1-2 orders of magnitude below many common accidents in daily living. It is consistant with public attitudes and actions toward widespread risks which have not been the subject of intensive publicity campaigns for reduction.

Comparison With Occupational Risk

The current situation and attitude in the occupational area are well summarized by Lowrance(1) as follows:

> "*It has traditionally been accepted that pursuing one's trade will almost inevitably bring a peculiar set of risks, and further, that such risks may allowably be greater than for Non-occupational activities*. This attitude has strong historical momentum. The justification has been that 'taking those chances is what you get paid for'." (Emphasis added)

> "Although people have always tried to reduce their work hazards, systematic effort has been made only in recent years, and even then, in just a few prosperous nations. In part this is due to a new general awareness and apprehension about subtle, chronic hazards such as noise, asbestos, and vinyl chloride. In part it is a manifestation of the recent years redistribution of social rights and power. *It is a relatively new development that society as a whole should show concern for the conditions in the mines and*

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(1) "Of Acceptable Risk, " William W. Lowrance, William Kaufmann, Inc., 1976, p. 89, 90.

> *foundries, or that society would offer to underwrite (as taxes, or as consumer costs) the alleviation of suffering in chemical plants and textile mills*." (Emphasis added)

> "Admirable though such a goal is, it has probably never been very closely approached in any country."

> "However, our *attitudes about* risks and our assignment of responsibility for minimizing them *still seem influenced by whether they are encountered on or off the job*." (Emphasis added)

> "Pursuit of occupation is still distinct from other activities, despite recent idealistic exhortations that work be indistinguishably integrated with the rest of our daily affairs."

In the OSHA testimony referred to previously, Dr. Wilson suggested a level of 10 deaths per million per year as an appropriate *goal* for occupational risk with progress towards this goal strongly conditioned by considerations of cost effectiveness. This would in effect be a de minimus point below which further reductions would not be required and resources would go to reduce risk in areas where it is much higher.

The 10/million/year level is substantially lower than any of the present occupational risks and does make workplace risks indistinguishable from our daily affairs. It also represents about the same risk as being in the room with a smoker and is at the *lower end* of the range 3-77 d/M/y for a variety of common household risks.

Continuing in the OSHA testimony cited previously, Wilson noted that the International Committee on Radiological Protection (ICRP) had used a factor of 30 to convert from occupational risk to the general public risk. Based on the recommended value of 10/million/year as a goal for occupational exposure application of this factor yields a value of about 0.3/million/year.

In more recent testimony at a FDA hearing on cancer-causing residues in edible products from food producing animals (6/22/79) he has suggested a somewhat higher level of 1/million/year which he considered to be a reasonable level for general exposure.

It should be added that in the above noted hearing(1) the FDA suggested a value of 0.015 d/M/y(2) as an acceptable level of risk. This value is smaller than the lowest Wilson suggestion by a factor of about 30 and is also a factor of about 20,000 smaller than the lower end of the occupational range of 30/million/year. It is also smaller than the risk from background radiation (draft GEIS) by a factor of 1500 and the risk of being struck by lightning by a factor of nearly 30. It is suggested that the FDA recommendation may be substantially too conservative.

Comparison with Common Involuntary Risks

The three approaches just described support a range of approximately 0.1 to 1 d/M/y as a reasonable level for general population risk. It is instructive to compare this range with a variety of common involuntary risks to the general public which are broadly accepted today. This comparison is shown in the following table in terms of risk factors, i.e., the ratio of the risk from the designated source to the value of 0.1 or 1 d/M/y. The natural incidence of cancer is also included to give a frame of reference.

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(1) February 1977 re DES, and June 1979 on residues in edible products.

(2) Lifetime risk of one/million divided by 66.7 years to convert to annual risk.

Source of Risk	Risk (d/M/y)	Reference	Risk Factor[(1)] at 0.1	at 1
Natural Phenomenon	0.5	Table III	5	0.5
One Airplane Trip per Year	3.5	Tables III & IV	35	3.5
In Room with Smoker	10	Table IV	100	10
Home Accidents	12	Table III	120	12
Natural Background Radiation	25	GEIS p. 6-71	250	25
Frequent Air Travel	115	Tables III and IV	1,150	115
Natural Incidence of Cancer	1,300	GEIS p. 6-43	13,000	1,300

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(1) Ratio of risk from designated source to suggested value of 0.1 or 1.

The upper end of the suggested range, i.e., 1 d/M/y, is twice as large as the risk from natural phenomenon, about four times less than an airplane trip, an order of magnitude less than common household accidents and natural radiation, and two orders of magnitude less than frequent air travel. It is certainly not inconsistent with these risks.

The lower end of the suggested range, 0.1 d/M/y, is five times less than being struck by lightning, two orders of magnitude less than the risk from accidents and natural radiation, and three orders of magnitude less than frequent air travel. It is also suggested that this should be considered as a deminimus level below which further reduction is not needed. This recommendation is based on the rationale that society is faced with a great number of far larger risks where funds can be allocated to produce much more beneficial results.

Conclusions

The foregoing analyses shows that a range of 0.1 - 1 d/M/y is a reasonable approximation of the level of risk that is acceptable to the general public. This range is recommended for use as a component of regulatory decisionmaking. It is not suggested that this be a rigid rule but a guideline conditioned by the number of people exposed and the costs to reduce risk. It is also assumed that the corresponding societal benefits, although not necessarily quantifiable, would be substantial.

GENERAL ANALYSIS OF SOCIETAL EXPENDITURES TO REDUCE RISK

Introduction

It was stated earlier that life is a series of risks, there is no such thing as a risk-free existance, and that society has limited resources to reduce risk. These facts make it imperative that informed, rational societal decisions be made regarding acceptable levels of risk.

These three reasons also make it equally imperative that the same kind of informed, rational decision be made regarding the level of cost effectiveness in reducing risk that is needed to justify the expenditure of society's resources. Stated simply, how much money should society expend to avert a premature health effect.

Costs are generally stated in dollars and health effects in human lives so that a highly emotional element of apparently putting a dollar value on human life is introduced into the decision-making when cost-effectiveness is considered. Cohen(1) provides an excellent discussion of the problem as follows:

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(1) B. L. Cohen, "Society's Valuation of Life Saving in Radiation Protection and Other Contexts," Health Physics (in print).

"Assigning a dollar value to a human life appears intuitively to be an immoral and repugnant subject, but actually we all do it frequently. For example, when we buy low priced tires rather than the type that cannot blow out, or when we decide not to have frequent medical check-ups, we are placing a dollar value on our own lives and even on the lives of our loved ones. The value of life saving is also an implicit element in public decision making. It is well recognized that divided highways bordered with gently sloping terrain free of obstacles that may provide targets for hard collisions are much safer than typical roads and hence can save lives, but we build only a small fraction of our highways with those features, only to save money. There are many ways in which medical care could be improved by expenditure of public funds, and surely these would save lives.

Perhaps the moral position in considering a dollar valuation of human lives is improved if we recognize that monetary costs largely represent human labor, both directly and indirectly in that the costs of materials largely represent the costs of labor to derive them —when we mine a mineral we don't pay the earth for it. The question we are really addressing then, <u>is how many man-hours or lifetimes of labor should be devoted to extending one person's life</u>." (Emphasis added)

Another worthwhile viewpoint is expressed by Linnerooth:(1)

> "Some have argued that the question, 'What is a life worth?' is poorly phrased and what we really want to know is, '<u>What is the value placed on a particular change in survival probability?</u>'" (Emphasis supplied)

In the final analysis, although cost effectiveness is expressed in units of dollars per fatality averted, it is really a measure of how much human labor should be expended to improve the survival probability of society in general. We each make cost-effectiveness decisions regularly that affect our own lives, society cannot afford <u>not</u> to make such decisions, and it is clearly in society's best interest to do so.

Technical Considerations

In order to examine what may be an appropriate level of cost-effectiveness it is useful to first develop a frame of reference based on current societal actions. A recent and comprehensive paper by Cohen(2) has been selected as the principal reference. [illegible] is provided as Attachment 3.

In the Cohen study situations have been identified where society is spending money in a substantial but not massive way to avert fatalities. For each situation the cost per fatality averted has been calculated with the results shown in Table VII.

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(1) J. Linnerooth, The Evaluation of Life-Saving: A Survey, Joint IAEA/IIASA Research Report, International Atomic Energy Agency, Vienna, Austria, 1977.

(2) B. L. Cohen, "Society's Valuation of Life-Saving in Radiation Protection and Other Contexts," <u>Health Physics</u> (in print).

TABLE VII

SOCIETAL EXPENDITURES TO AVERT RISK(1)
(1975 Dollars)

Item	$ per Fatality Averted
Medical Screening and Care	
cervical cancer	25,000
breast cancer	80,000
lung cancer	70,000
colorectal cancer:	
fecal blood tests	10,000
proctoscopy	30,000
multiple screening	26,000
hypertension control	75,000
kidney dialysis	200,000
mobile intensive care units	30,000
Traffic Safety	
auto safety equipment - 1966-70	130,000
steering column improvement	100,000
air bags (driver only)	320,000
tire inspection	400,000
rescue helicopters	65,000
passive 3-point harness	250,000
passive torso belt-knee bar	110,000
driver education	90,000
highway construction-maintenance practice	20,000
regulatory and warning signs	34,000
guardrail improvements	34,000
skid resistance	42,000
bridge rails and parapets	46,000
wrong way entry avoidance	50,000
impact absorbing roadside devices	108,000
breakaway sign, lighting posts	116,000
median barrier improvement	228,000
clear roadside recovery area	284,000
Miscellaneous Non-Radiation	
food for overseas relief	5,300
sulfur scrubbers in power plants	500,000
smoke alarms in homes	250,000
higher pay for risky jobs	260,000
coke fume standards	4,500,000
Air Force pilot safety	2,000,000
civilian aircraft (France)	1,200,000
Radiation Related Activities	
radium in drinking water	2,500,000
medical X-ray equipment	3,600
ICRP recommendations	320,000
OMB guidelines	7,000,000
radwaste practice - general	10,000,000
radwaste practice - ^{131}I	100,000,000
defense high level waste	200,000,000
civilian high level waste	18,000,000

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(1) B. L. Cohen, "Society's Valuation of Life Saving in Radiation Protection and Other Contexts," Health Physics (in print).

It is immediately evident that there are very wide variations in the values shown. In the lowest group are the medical care and traffic safety categories plus the items of overseas food, smoke alarms, and higher pay for risky jobs from the miscellaneous non-radiation category which show a range of $5,000 to $400,000 per fatality averted. These are generally routine, low to moderate risk items impacting on the entire population. There has been no concerted large-scale publicity or widespread organized efforts for further risk reduction.

The final category, radiation related activities, with very large expenditures up to $200,000,000 per health effect. Cohen(1) provides an excellent explanation:

> "But aside from these few cases, it seems difficult to justify the differences morally. Indeed, one could argue that it is highly immoral for $100 million in funds obtained from the general citizenry to be spent in saving one life from ^{131}I emissions when that same money could save 2000 lives if it were spent on medical or traffic safety programs which are being held back for lack of money.

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(1) B. L. Cohen, "Society's Valuation of Life-Saving in Radiation Protection and Other Contexts," Health Physics (in print).

> Sociologists and economists usually try to explain rather than to justify discrepancies like those in the table. Human fears are not necessarily correlated with actual dangers, and government agencies are more concerned with allaying fears than with averting dangers. This could be interpreted as a cynical disregard for human welfare, but on the other hand, it could be viewed as participatory democracy functioning properly by being responsive to the desires of the citizenry."
>
> "The only solution to this dilemma would seem to be education, and it is clear from Table 1 that the radiation protection community has done a particularly poor job of educating the public."

This presentation is an attempt to put the problem in perspective and provide the education suggested.

Societal Considerations

Guideline for Cost-Effectiveness

There is a large body of literature available today that discusses societal expenditures to avert risk. A substantial and representative portion of the suggested values are summarized in Table VIII.

The table is divided into two parts, suggested or actual expenditures and extimated societal costs. The first group represents interpretations by various experts and governmental agencies or indications by its own actions of how much society considers appropriate to spend to avert a premature health effect. The second group shows attempts to evaluate the actual costs to society of such premature effects. It provides a measure of a reasonable minimum value.

Although there are much higher and lower values at either end, there is a large measure of agreement in the range of $250,000-500,000 as an appropriate level of expenditure. This is also the same range found previously (Table VII, page 30) for actual societal decisions in cases of generally routine, low to moderate risks impacting on large populations. It is also well above the estimated societal costs shown. It is suggested, therefore, that this range is particularly appropriate to evaluate the cost-effectiveness of the various control methods proposed in the draft GEIS.

Time Period for Health Effect Integration

The tailings from uranium milling can be a potential source of radon for many years. Some have suggested that predicted accumulated health effects for extremely long time periods into the future should be used as justification for extreme measures <u>today</u> to prevent future radon emanation. In thie discussion of this philosophical question the staff has

TABLE VIII

SUGGESTED SOCIETAL EXPENDITURES TO AVERT HEALTH EFFECTS

Source	$/Health Effect(1)	Rational or Calculation Basis
Suggested or Actual Expenditures		
NRC(10-CFR-150)(2) Appendix I	~4,000,000	Codifying existing practice for certain high level wastes.
Richard Wilson(3)	1,000,000	$/person/year for a 10^{-5} level of risk.
BEIR-1972 (Page 70)	~50,000-500,000	"The total future cost of one man-rem in terms of health cost paid for in present dollars. ." (12-120 $/man-rem)
EPA-40CFR-190	250,000-500,000	-
Bernard Cohen(4)	250,000-500,000	-
Keith Schaiger(5)	220,000-440,000	$50,000 as economic decrement per cancer, 2×10^{-4} per man-rem yields $10/man-rem as marginal utility value. Increased as basis of BEIR-1972.
Joshua Ledenburg(6)	400,000 Max.	Double health expenditures for a 20% improvement in health.
Moskowitz, et el (7)	120,000	$6,000 per year of life lost times 20 years lost per cancer death.
Asbestos Litigation(8)	450,000	Highest court award in 1978.
	70,000	Average settlement of asbestos workers' 3rd party liability suits.
Estimated Societal Costs		
National Safety Council(9)	110,000	Estimated dollar cost of death.
Epstein(10)	49,000	$18 billion annual estimated cost to society for 365,000 annual cancer deaths.

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1. Where suggested value is given in $/man-rem the GEIS factor of 2.3×10^{-4} health effects per year per man-rem per year has been used to convert to $/health effect.
2. Factor given in $1000/man-rem. If applied to the thyroid value would be higher by a factor of 20.
3. Direct Testimony presented on OSHA Docket No. H-090, "Proposed Regulations for Identification, Classification, and Regulation of Toxic Substances Posing a Potential Occupational Carcinogenic Risk."
4. Direct Testimony presented at the NRC Hearing on NUREG 0511, Albuquerque, New Mexico, October 18, 1979.
5. "Evaluation of 40 CFR-190, Environmental Radiation Protection for Nuclear Power Operations." Prepared for the American Mining Congress, May 1977.
6. "How Safe is Safe?--The Design of Policy on Drugs and Food Additives," National Academy of Sciences, 1974, p. 68.
7. M.E.L. Moskowitz, J. G. Saenger, G. Kereiakes, K. Bahr, and S. Pemmaraju, November 1976. Cost-Risk-Benefit in Breast Cancer Screening, Proc. IEEE Conf. on Cybernetics and Society, pp. 228-235, Washington, DC. ($6000 per year is actual value given. Number of years lost per cancer is an estimate supplied to calculate equivalent cost per health effect.)
8. Business Insurance, June 11, 1979. Hartford Courant, Sunday, March 4, 1979.
9. National Safety Council, 1975, Traffic Safety Memo No. 113, July 1975, Chicago, Il.
10. "Cancer and the Environment," The Bulletin of Atomic Scientists, March 1977, p. 22.

quite correctly pointed out that such long term predictions would require assumptions about the future course of climatic and geological changes on the planet due both to natural evolution and changes caused by man's activities. Assumptions about the future course of civilization, particularly about future societal attitudes toward life and appropriate risk would also be required. The development of the predictions needed at the levels of confidence necessary to justify large commitments of societal resources today present a number of serious problems.

All of the long term health effects predicted in the GEIS are based on the assumption that there will not be a cure for cancer within the time frames considered. Totally different scenarios can be devised depending on the assumption that is made about the future success of medical intervention in cancer. The possible validity of the GEIS assumption and the impact of a cure were discussed by Dr. Cohen.(1)

> "If there is a cure in 100 years the already small effects would be reduced by a further factor of 1100, and if the cure comes in 1000 years, the effects are reduced by a factor of 110. About 70% of radon-induced lung cancers are a type called "small cell undifferentiated," and there has recently been good success in treating this type by chemotherapy with cytoxin, vincristin, and adriamycin."

Predictions far into the future contain the implicit assumption that society puts the same value on future lives as on the lives of those now living. If this were true, society today would be spending much more money on medical research to save future lives than it is spending on health care. This is not the case and even the research expenditures that are made are generally targeted at short-term payoffs.

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(1) Report by Dr. B. L. Cohen, "Perspective on Risk," Part III, Item A.4.

In the examination of very long time spans (hundreds of thousands to millions of years) in the future, it should also be realized that the mining of uranium ore does not alter the net population exposure but merely alters the time at which they occur. The reason for this is discussed by Cohen.(1)

> "North American rivers carry 86 gm of sediments plus 33 gm of dissolved material in the oceans each year for each square meter of continental area. Dividing the sum of these, 119 gm/m^2 by the density of rock, 2.7×10^6gm/m^3, indicates that the surface of the continent is being eroded away at an average rate of 44 meters of depth per million years (44×10^{-6} meters/year). As a result of this erosion, it is reasonable to assume that essentially all uranium in the ground will eventually have its turn near the surface where it will contribute to environmental radon in the atmosphere. In this perspective, bringing uranium to the surface as in mining of uranium, coal, or phosphate, has no net effect over long time spans. It merely shifts the time period during which this particular uranium contributes radon to the atmosphere from some future time to the present."

> "About half of our uranium is surface mined from a depth of of less than 100 meters, and within this range the uranium is roughly uniformly distributed with respect to depth."

The rate of denudation calculated by Cohen is about 25 times smaller than that estimated on page 9-34 of the GEIS but the overall effect is the same. Either now or sometime in the future, the radioactivity will reach the surface and whatever population is present at that time will be exposed.

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(1) B. L. Cohen, "Society's Valuation of Life Saving in Radiation Protection and other Contexts." *Health Physics* (in print).

In summary, the AMC believes that there is no question that great changes affecting mankind and civilization will occur over the next several hundred, thousand, hundred thousand or more years and that there is no reasonable way to predict what such changes will be. Basing today's decisions upon predictions of conditions and societal attitudes hundreds and thousands of years into the future is a meaningless exercise that is both unjustified and conceptionally unsound. A relatively short period, not exceeding one hundred, or at most a few hundred years, where a reasonable prediction of societal attitudes, the state of civilization, and the state of the planet can be made, should be used for the analysis of the cost-effectiveness of various alternatives.

It could be argued that this approach would subject future generations to risks for which they receive little benefit. It could be argued equally well that the risk from cancer will not exist in 100 years or that a nuclear holocaust, natural disaster, or large scale climatic changes will change the life span and quality of life to the extent that extremely low level incremental risk from a very small additional increment of radon is lost among larger concerns. Use of a limited integration period presents the most rational basis for present decision making.

Conclusions

Examination of the literature on societal attitudes on expenditures to avert risk suggests that a range of $250,000-500,000 per health effect averted is particularly appropriate to evaluate the cost-effectiveness of the various control measures proposed in the draft GEIS. This would be a guideline, not a rigid rule.

Based upon considerations of the impact of a possible cure for cancer and the inability to make long-term predictions of either the geological state of the planet or the condition and attitudes of society with any degree of reliability, it was concluded that a period of about 100 years was appropriate for use in cost-effectiveness evaluation.

RISK FROM VARIOUS LEVELS OF RADON FLUX CONTROL

Introduction

In the draft GEIS analysis the greatest risk to the general public from uranium milling is from radon emanation from the mill tailings after final disposal. In the analysis of this problem presented in the draft GEIS, projected Continental health effect expressed as total health effects over 100, 1000, and 100,000 year periods were examined at a series of different depths of cover. It is clear from the dose committments in Table 6.39, page 6-72, that there are very substantial differences in the level of risk for the population of the Regions and for those living in the remainder of the Continent. The use of total numbers for health effects also makes it difficult to compare the rates of risk experienced with other risks commonly encountered in the workplace and by the general public.

The costs of cover for the tailings used in this GEIS analysis were estimated on the basis of a hypothetical combined cover consisting of one-third Soil A, one-third Soil B, and one-third a combination of 0.6 meters of clay plus the remainder Soil A. This makes it difficult to ascertain the effects of real situations where only certain soils will be available. Also, only average costs per health effect averted were provided. This is misleading because the cost of cover is directly proportional to the depth used while the corresponding health effects decrease in an exponential manner. The first foot added is more effective than the second, etc. In this situation the critical variable is not the overall average cost per health effect averted but what does an incremental additional expenditure provide in terms of the incremental number of estimated health effects which it averts.

In order to provide a more comprehensive basis for a properly informed societal decision, the AMC has expanded the analysis, based entirely on the risk and cost data provided in the GEIS, in the following manner:

1. Regional and Far Field(1) risks are shown separately. Results are expressed as deaths per million people exposed per year so that the level of absolute risk can be compared to other risks.
2. Costs for various levels of cover have been calculated separately for all three soil options, i.e. Soil A, Soil B, and 0.6 meters of clay plus Soil A. These costs have been used to find the incremental cost per incremental health effect averted for various levels of control. The results are compared to the costs to avert other risks described in the previous section.

Evidence has been presented in other AMC testimony that the risks given in the GEIS are substantially overestimated and the average industry costs are underestimated. For purposes of comparison, a parallel analysis to the one just described using risks and costs which the AMC believes are more realistic, but still conservative, is also presented.

For clarity in presentation, the discussion of risk comparisons will be given in this section. The cost-effectiveness results will be treated in the following section.

Estimation of Risks

GEIS Basis

Table 12.5, page 12-18, of the GEIS presents a series of cumulative costs and cumulative health effects based on the persistent total Continental environmental dose committments given in Table 6.39. To develop this table the Continental dose commitment was combined with the health effect factors from Appendix G, Table G-7.1 to obtain the persistent annual Continental health effects for the base case flux of 450 pCi/m^2-sec. The health effects at other flux levels were obtained by ratio.

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(1) Far-field is defined as Continental minus Region. See GEIS 6.4 and 6.4.1, page 6-64.

Table 6.39 also shows the component Regional and U.S. Non-Regional, Mexico, and Canada (hereinafter referred to as Far-Field) dose commitments that made up the total Continental doses. The same calculation procedure used by the staff has been applied to the component doses to develop a complete picture of Regional, Far-Field, and Continental effects. Both cumulative and incremental health effects for each successive reduction in flux are shown for all levels of control. The Near-Field and Continental populations of 517,000 and 460 x 10^6, respectively, have been used to express the cumulative risks as a rate in terms of deaths/million/year.

A "background risk factor" (BRF) for each flux rate has also been calculated as the ratio of the appropriate risk from natural background radiation sources to the risk from radon emination from the tailings. A BRF of a thousand means that the risk from background radiation is a thousand times larger than the calculated risk from uranium milling.

The various factors calculated are summarized in Table VIII. It is fully recognized that the accuracy of all of the calculated values is substantially less than the number of significant figures shown in the table. It is necessary, however, to retain such figures to be able to show trends and to make relative comparisons.

AMC Basis

It was repeatedly stated in the GEIS that every effort was made to present a conservative picture. As an example, Section 5.3.2, page 5-7 states:

> "These released present what the staff considers to be the upper bound of "worst case" situation for the model mill."
> (Emphasis added)

The "worst case" situation for the model mill was then multiplied by the 82 model mills to obtain the values for the overall impacts.

TABLE IX

PERSISTENT SOMATIC HEALTH EFFECTS OF VARIOUS RADON ATTENUATION LEVELS

	REGIONAL(1)(4)				FAR FIELD(2)(5)				CONTINENTAL(3)			
	Est. Health Effect		Risk(6)	(7)(8)	Est. Health Effect		Risk(6)	(7)(8)	Est. Health Effect		Risk(6)	(7)(8)
Flux Limit (pCi/m^2-sec.)	Cumulative	Incremental	(d/M/y)	BRF	Cumulative	Incremental	(d/M/y)	BRF	Cumulative	Incremental	(d/M/y)	BRF
450	2.10	0	4.06	18.2	7.60	0	0.0165	1,515	9.70	0	0.0211	1,184
100	0.46	1.64	0.89	83.1	1.67	5.93	0.0036	6,944	2.13	7.57	0.0046	5,435
50	0.23	0.23	0.45	164	0.84	0.83	0.0018	13,890	1.07	1.06	0.0023	10,870
10	0.046	0.184	0.089	831	0.167	0.67	0.00036	64,440	0.213	0.86	0.00046	54,350
5	0.023	0.023	0.045	1644	0.084	0.083	0.00018	139,000	0.117	0.106	0.00023	108,700
3	0.0139	0.091	0.027	2740	0.0501	0.0339	0.00010	250,000	0.064	0.043	0.00014	178,600
2	0.0091	0.0048	0.018	4111	0.0329	0.0172	0.00007	357,000	0.042	0.022	0.00009	278,000
1	0.0045	0.0046	0.0087	8505	0.0165	0.0164	0.00004	625,000	0.021	0.021	0.00005	500,000

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(1) Includes regions encompassing 82.2 mills. Total population assumed constant at [(82.2 mills)/(12 mills/region)] (75,500 people/region) = 517,000.

(2) Far Field is made up of U.S. Non-Regional, Canada, and Mexico. Total population assumed constant at 460×10^6.

(3) Continental effects are the sum of Regional plus Far Field effects.

(4) Health effects calculated by ratio of 2.1/9.7 applied to the Continental effects.

(5) Health effects calculated by a ratio of 7.6/9.7 applied to Continental effects.

(6) Risks calculated as cumulated somatic health effects divided by the population at risk. Expressed as deaths/million/year.

(7) This factor compares the risk from natural background radiation sources to the risk from uranium milling, i.e. the factor equals $\frac{\text{Risk from Background}}{\text{Risk from Milling}}$. A factor of 1000 means the background risk is 1000 times larger than the risk from milling.

(8) Background calculated risks as follows:

Near field (Regional): Whole body 0.143 rem, bone 0.250 rem, lung 0.704 rem which gives an annual risk of $7.4x10^{-5}$ or 74 death/M/y (Table 6.28, page 6-52).

Far Field and Continental: Whole body 0.080 rem, bone, 0.172 rem, lung 0.161 rem for an annual risk of $2.48x10^{-5}$ or 25 d/M/y (Table 6.37, page 6-71). Factors given in Table G-7.1 used to convert dose to risk.

A. General Note:

It is fully recognized that the accuracy of all of the calculated values is far less than the number of significant figures shown in the table. It is necessary to retain the figures to show trends.

This dedication to conservatisim has two implicit assumptions of very dubious validity. First, there are a substantial number of factors which make up the dose commitment and risk factor estimates that yield the final value of calculated health effects. It is highly improbable that "worst case" conditions will occur simultaneously for all factors or even for a majority of them at any particular mill.

Second, it is assumed that not only do all of the worst cases occur simultaneously at any particular mill but also that they all occur all of the time at all 82 of the mills. This is a pyramiding of safety factors beyond reasonable conservation and makes it difficult to assess the meaning of the end result.

In order to put the risk assessment in a more reasonable perspective, three areas in the GEIS need to be adjusted:

1. The number of model mills required.
2. The radon flux from the uncovered tailings from the base case model mill.
3. The estimates of population risk.

The cumulative impacts in the GEIS are based on a projected nuclear generating capacity of 380 GW_e and an enrichment tail of 0.25% A recent DOE publication(1) gives a mid-case value of 255 GW_e in the year 2000 and an enrichment tail of 0.2%. This requirement could be met by 50 model mills vs the 82 in the GEIS, assuming 6000 MT from unconventional sources. The AMC believes that this is a more realistic and therefore more appropriate value to use in the estimation of environmental impacts.

The adjustment from 82 to 50 mills could be made by keeping the 12 mill per region configuration and reducing the total number of regions or by keeping the number of regions constant and reducing the density of mills per region. The 12 mill per region assumption is considered to be

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(1) John Kleminic, D.O.E., October 1978.

substantially too high and if fewer mills are required, there will be less tendency for them to be concentrated in large numbers in any particular small area. The option of keeping the number of regions constant and reducing the mills per region has been selected. This results in a reduction in persistant health effects in both the Regional and Far-Field operations by a factor of 50/82.

The base case estimates assume a radon exhalation rate of 450 pCi/m^2-sec. for the uncovered tailings at the model mill. In contrast to this Appendix P, page P-2, in the GEIS, calculates uncovered tailings flux for 450 pCi Ra-226/g to be 209 pCi/m^2-sec. An ANL paper (Momeni, et al) given in February 1979 at a Health Physics Society Symposium presents experimentally measured flux rates of 0.64 and 0.30 pCi Rn/m^2-sec. per pCi Ra-226/g for acid and carbonate leached tailings respectively. The former value (acid leaching) would give 288 pCi/m^2-sec. for bare tailings.

A base case value of 250 pCi/m^2-sec. is a more realistic overall average flux level for environmental impact analysis. Since radon is the principal source of Regional and Far-Field persistant radiological impacts, a factor of 250/450 has been applied to the GEIS values to adjust to a more realistic value.

The extent to which health effects are overestimated is a complex question that has been discussed in detail in AMC's testimony. Both the estimation of dose committment and the estimate of the resulting health effects must be considered. Impact Associates(1) has shown that certain dose commitments may be overestimated by factors ranging from 4 to 40. Dr. Schaiger(2) has suggested a factor of 40-100 overestimation of the health effects due to radon. Mr. Swent(3) has examined a number of factors not generally covered by the other testimony and estimates that these lead to an overestimation by a factor of about 6.

On the basis of their information it appears that persistent health effects have been overestimated in the GEIS by <u>at least</u> a factor of ten. This factor will be used in this analysis. Note that this factor still includes linear, non-threshhold extrapolation to obtain risk estimates at low exposure levels.

The combination of these measures of conservativeness yields a factor that can be applied to the earlier risk calculations based on the GEIS figures to provide a more <u>realistic</u> estimate of risk. Thus:

Factor = (No. of Mills)(Radon Flux)(Health Effect Factor)

$$\text{Factor} = \left(\frac{50}{82}\right)\left(\frac{250}{450}\right)\left(\frac{1}{10}\right) = 0.034$$

This factor can be applied directly to the risks shown previously in Table IX to adjust for more realistic but still conservative conditions. It should be noted, however, that since a part of the basis for the reduction in risk is a change in the radon flux from uncovered piles from 450 to 250 pCi/m^2-sec. a corresponding adjustment must be made in the related flux to put the two estimates on a directly comparable basis.

These adjustments of risk and corresponding flux level have been made in the Regional values from Table IX and the results are summarized in Table X. Only the Regional results have been calculated since it is

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(1) Impact Associates, written and direct testimony, NRC Hearing on NUREG 0511, Albuquerque, New Mexico, October 18, 1979.

(2) K. Schaiger, written and direct testimony, NRC Hearing on NUREG 0511, Albuquerque, New Mexico, October 18, 1979.

(3) L. Swent, written and direct testimony, NRC Hearing on NUREG 0511, Albuquerque, New Mexico, October 18, 1979.

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TABLE X

PERSISTENT REGIONAL SOMATIC HEALTH EFFECTS AT VARIOUS RADON ATTENUATION LEVELS

	BASE CASE(2)				Adjusted(3)	REALISTIC ESTIMATE			
	Estimated Health Effects		Risk(4)	(5)(6)		Estimated Health Effects		Risk(4)	(5)(6)
Flux Limit (pCi/m^2-sec.)	Cumulative	Incremental	(d/M/y)	BRF	Flux Limit (pCi/m^2-sec.)	Cumulative	Incremental	(d/M/y)	BRF
450	2.10	0	4.06	18.2	250	0.071	0	0.14	530
100	0.46	1.64	0.89	83.1	56	0.016	0.055	0.031	2,400
50	0.23	0.23	0.45	164.0	28	0.008	0.008	0.015	4,600
10	0.046	0.184	0.089	831.0	5.6	0.0016	0.0064	0.0031	24,000
5	0.023	0.023	0.045	1,644.0	2.8	0.0008	0.0008	0.0015	49,000
3	0.0139	0.091	0.027	2,740.0	1.7	0.0005	0.0003	0.0010	74,000
2	0.0091	0.0048	0.018	4,111.0	1.1	0.0003	0.0002	0.0006	123,000
1	0.0045	0.0046	0.0087	8,505.0	0.6	0.00015	0.00015	0.0003	246,000

(1) Includes the same regions encompassing either 82.2 or 50 mills. Total population assumed constant at (82.2 mills)/(12 mills/region) (75,500 people/region) = 517,000.

(2) Base Case figures from Table 9.

(3) Number of mills adjusted 50/82.2; flux adjusted 250/450; dose-risk factor adjusted 1/10.

(4) Risks calculated as cumulated somatic health effects divided by the population at risk. Expressed as dealths/million/year.

(5) This factor compares the risk from natural background radiation sources to the risk from uranium milling, i.e. the factor equals $\frac{\text{Risk from Background}}{\text{Risk from Milling}}$.

(6) Background risks as follows: Near-Field (Regional): Whole body 0.143 rem, bone 0.250 rem, lung 0.704 rem which gives an annual risk of $7.4\text{x}10^{-5}$ or 74 death/M/y (Table 6.28, page 6-52).

evident from Table IX that they are higher than those for the Far-Field by a factor of about 250 and are thus the most critical.

Comparison of Risks

Annual rates of risk for the Regional, Far-Field and Continental populations based on the GEIS values (Table IX) are shown as a function of radon flux in Figure 1. The regional values from the AMC assumptions (Table X) are also given. A variety of occupational and general public risks from Table V and the suggested guideline range of 0.1-1 d/M/y developed previously are also shown for comparison. Where a range of risk occurs in the comparative information, the mid-range value is indicated and the range is listed. Note that these risks are not related to any particular radon flux and are presented in an orderly fashion in the open portion of the figure.

It should also be noted that the wide range of risks to be included made it necessary to use a logarithmic scale on the vertical axis. This makes it more difficult to visualize the true differences and it should be emphasized that each major division represents a change of a factor of 10, i.e., an order of magnitude.

Consider first the risks taken directly from the draft GEIS. The Far-Field and Continental risks shown by the bottom two curves are lower than those for the Regional population by a factor of about 200 and 250, respectively. On a Far-Field basis the risk from uncovered tailings is nearly an order of magnitude below the lower end of the suggested acceptable range and is about the same as the FDA recommendation of an acceptable level for carcinogenic residues in meat products. It is hard to see how any cover is justified on a technical basis due to risks to the Far-Field or Continental population.

The Regional risks (GEIS) are shown by the upper curve in the figure. At the base case level of no control, i.e., a flux of 450 pCi/m^2-sec, the

RISK COMPARISON

REGIONAL AND CONTINENTAL EXPOSURES

OCCUPATIONAL AND DAILY LIVING

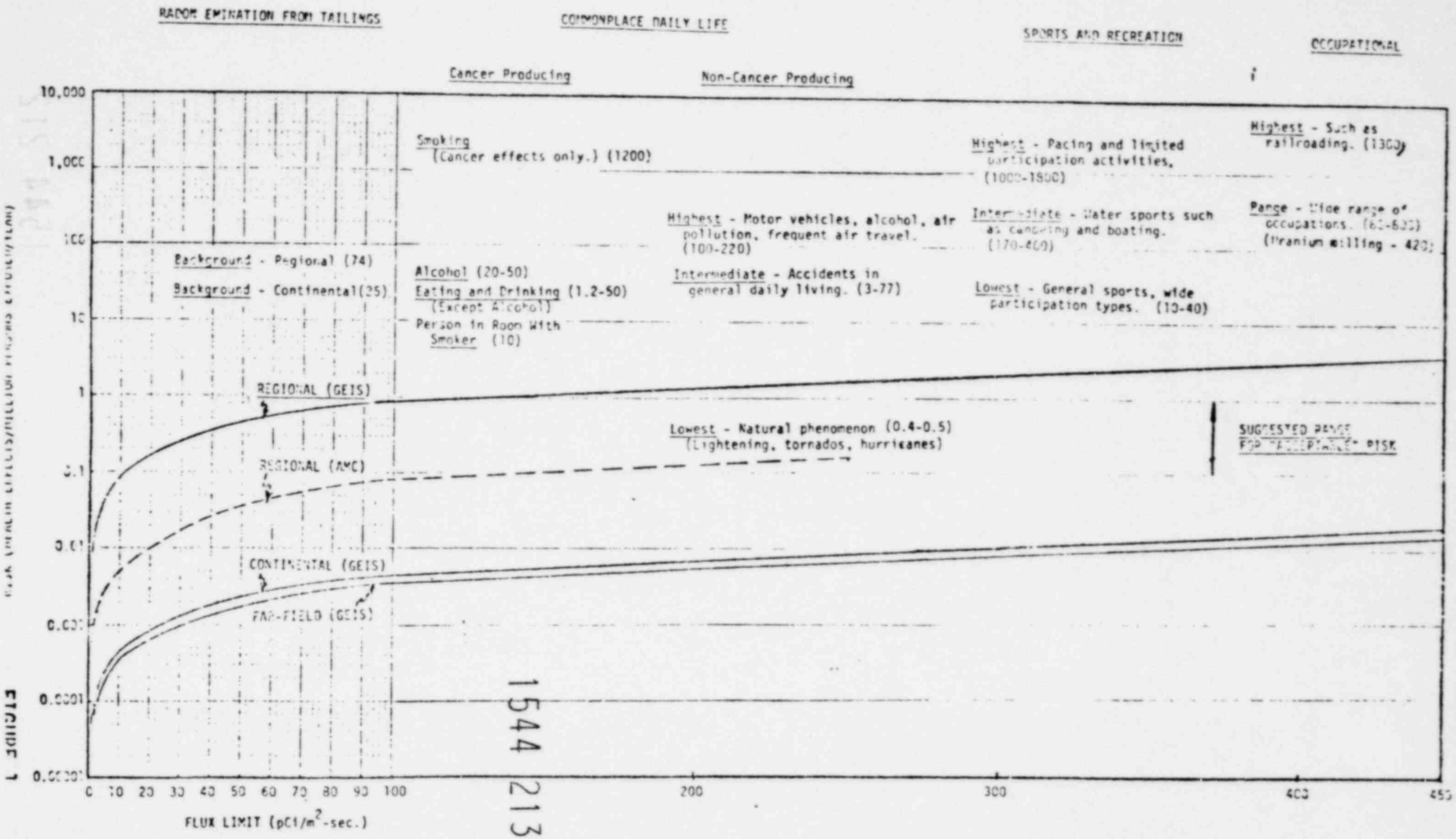

FIGURE 1

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1.1

risk is about 4 d/M/y. This is about 20 times smaller than that from natural background radiation, about three times smaller than being in a room with a smoker or common household accidents and is about ten times greater than being struck by lightning. It is, however, above the suggested acceptable range of 0.1-1 d/M/y and indicates that, if the GEIS estimates are correct, some amount of cover to lower radon flux to the 10-100 pCi/m^2-sec. range is appropriate based on risks to the Regional population. The 2 pCi/m^2-sec. requirement suggested by the GEIS is clearly not supported by the risks.

Consider next the Regional risks based on the AMC realistic adjustments. The risk from uncovered tailings is at the low end of the range suggested so that the technical basis for cover is very marginal. At a flux of 25 pCi/m^2-sec. the risk matches the FDA suggestion for food residues. The 2 pCi/m^2-sec. suggestion obviously has even less support than given by the GEIS values.

Although the various general population risks are shown in the figure, a useful perspective can be gained by examining the specific numerical ratios shown in the following table. These risks have been selected as representative of involuntary risks which are acceptable to the population in general. Although there have been some limited moves to reduce involuntary exposure to smoking and to reduce home accidents, nothing approaching expenditures of the hundreds of millions of dollars that would be needed to achieve a major reduction. Nothing has been seriously advanced to lower the substantially greater hazards due to radiation exposure during air travel. There has been no move to warn against nor limit travel to parts of the country receiving high background radiation nor any recommendatior that people should not live in those parts of the country.

RISK COMPARISON - REGIONAL POPULATION[1]

(pCi/m^2-sec.)	(d/M/y)	Natural Phenomena[3] (Ratio)	One Airplane Trip per Year [4] (Ratio)	In Room with Smoker [5] (Ratio)	Home Accidents[6] (Ratio)	Natural Background Radiation[7] (Ratio)	Frequent Air Travel[8]
BASE CASE							
450[2]	4.06	0.1	1	3	3	20	30
50	0.45	1	8	20	30	200	260
10	0.089	6	40	100	100	800	1300
2	0.048	30	200	600	700	4000	6400
REALISTIC ESTIMATE							
250[2]	0.28	2	13	40	40	300	410
50	0.05	8	70	170	200	1500	2300
10	0.01	50	350	1000	1200	7400	11500
2	0.005	100	700	2000	2400	14800	23000

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1. All ratios less than 100 rounded to one significant figure, those greater than 100 have been rounded to two significant figures.
2. Uncovered tailings base flux.
3. Risk = 0.5 d/M/y, Table III.
4. Risk = 3.5 d/M/y, Tables III and IV.
5. Risk = 10 d/M/y, Table IV.
6. Risk = 12 d/M/y, Table III.
7. Risk = 74 d/M/y, Table I.
8. Risk = 115 d/M/y, Tables III and IV.

For the GEIS figures where conservative assumptions are repeatedly compounded, the Regional risk from uncovered tailings is about ten times greater than being struck by lightning, about the same as a single airplane trip, three times smaller than being in the room with a smoker and common home accidents, twenty times smaller than natural background radiation, and thirty times smaller than frequent air travel. With the more realistic but still conservative AMC values the same risks range from half that from lightning to 1 to 3 orders of magnitude less than the other risks listed. These risks apply only to the ~500,000 people that are predicted to be living in the regions around the mill. The risks to the remaining population would be less by a further factor of about 200.

At a flux of 50 pCi/m^2-sec. the GEIS based Regional risks range from about the same as being struck by lightning to 10 to 200 times less than the other risks cited. The corresponding AMC values range from 10 to 2300 times smaller than the risk from the tailings, i.e., one to more than three orders of magnitude. There is clearly no reason to require flux limits as low as 50 pCi/m^2-sec. based on population risks. At the 2 pCi/m^2-sec. level recommended, the GEIS risks range from 30 to 6400 times smaller than the common general public risks and the AMC values from 100 to 23,000 times smaller. Even the GEIS values do not support the need to achieve these levels.

Conclusions

The comparison of the absolute risks from uranium milling to other risks experienced and found acceptable to society shows that, on an overall Continental basis, using even the grossly conservative values in the GEIS, there is little technical justification for any cover on the tailings piles.

Examination of the Regional risks based on the GEIS values shows that a maximum flux in the range of 10-100 pCi/m^2-sec. is a reasonable guideline. The more realistic, but still conservative, AMC estimates suggest that there is no strong technical reason to require flux levels below 100 pCi/m^2-sec. The value of 2 pCi/m^2-sec. recommended in the GEIS is totally without support.

COST EFFECTIVENESS OF VARIOUS LEVELS OF RADON FLUX CONTROL

Introduction

It was pointed out in the previous section that the draft GEIS analysis of cost-effectiveness was difficult to use as a basis for informed decisions because a hypothetical combined cover was used and only average rather than incremental costs and health effects were provided. In this section the more detailed analysis suggested will be provided using costs recommended in the GEIS and found by the AMC. It should be noted that cost-effectiveness should consider all of the health effects involved so Continental figures are used in this analysis.

Estimation of Incremental Costs Per Incremental Health Effect Averted

The GEIS presented a flux control cost comparison in terms of a combined cover of an average composition. It is more useful to examine the components individually. Total and incremental industry costs for each successive level of flux control using the cost figures given in the GEIS have been calculated for Soil A, Soil B., clay and a combination of 0.6 m clay plus Soil A and are listed in Table XI. The corresponding cover needed to attain various flux levels for each type of material is also included and the results are shown in Figure 2. The figure is basically a more complete version of Figure 9.1, page 9-25 of the GEIS except that total thickness, not just that of the soil cover over the clay is given.

In other testimony the AMC has presented evidence that the average overall industry costs have been substantially underestimated in the GEIS. A factor of two has been selected as a conservative representation of the degree of underestimation for use in this analysis. Total and incremental cover costs have been calculated using this factor applied to the GEIS costs in the same manner just described. Results are summarized in Table XII.

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TABLE XI

VARIOUS COVER REQUIREMENTS FOR RADON FLUX ATTENUATION

	Soil A			Soil B			Clay			0.6m Clay + Soil A		
Flux Limit (pCi/m^2-sec.)	Depth(1) Req'd. (m)	Total(2) Ind. Cost(4) ($MM)	Incremental Ind. Cost(4) ($MM)	Depth(1) Req'd. (m)	Total(2) Ind. Cost(4) ($MM)	Incremental Ind. Cost(4) ($MM)	Depth(1) Req'd. (m)	Total(2) Ind. Cost(4) ($MM)	Incremental Ind. Cost(4) ($MM)	Depth(1) Req'd. (m)	Total(2) Ind. Cost(4) ($MM)	Incremental Ind. Cost(($MM)
450	0	0	-	0	0	-	0	0	-	0	0	-
100	1.14	98	98	2.32	199	199	0.27	23	23	-	-	-
50	1.66	142	44	3.31	290	91	0.39	33	10	-	-	-
10	2.88	246	104	5.87	502	212	0.68	58	25	0.92(3)	79	79
5	3.40	291	45	6.94	593	91	0.80	68	10	1.45	124	45
3	3.79	324	33	7.73	661	68	0.89	76	8	1.83	157	33
2	4.09	350	26	8.36	715	54	0.96	82	6	2.13	174	17
1	4.62	395	45	9.42	805	90	1.08	92	10	2.66	227	53

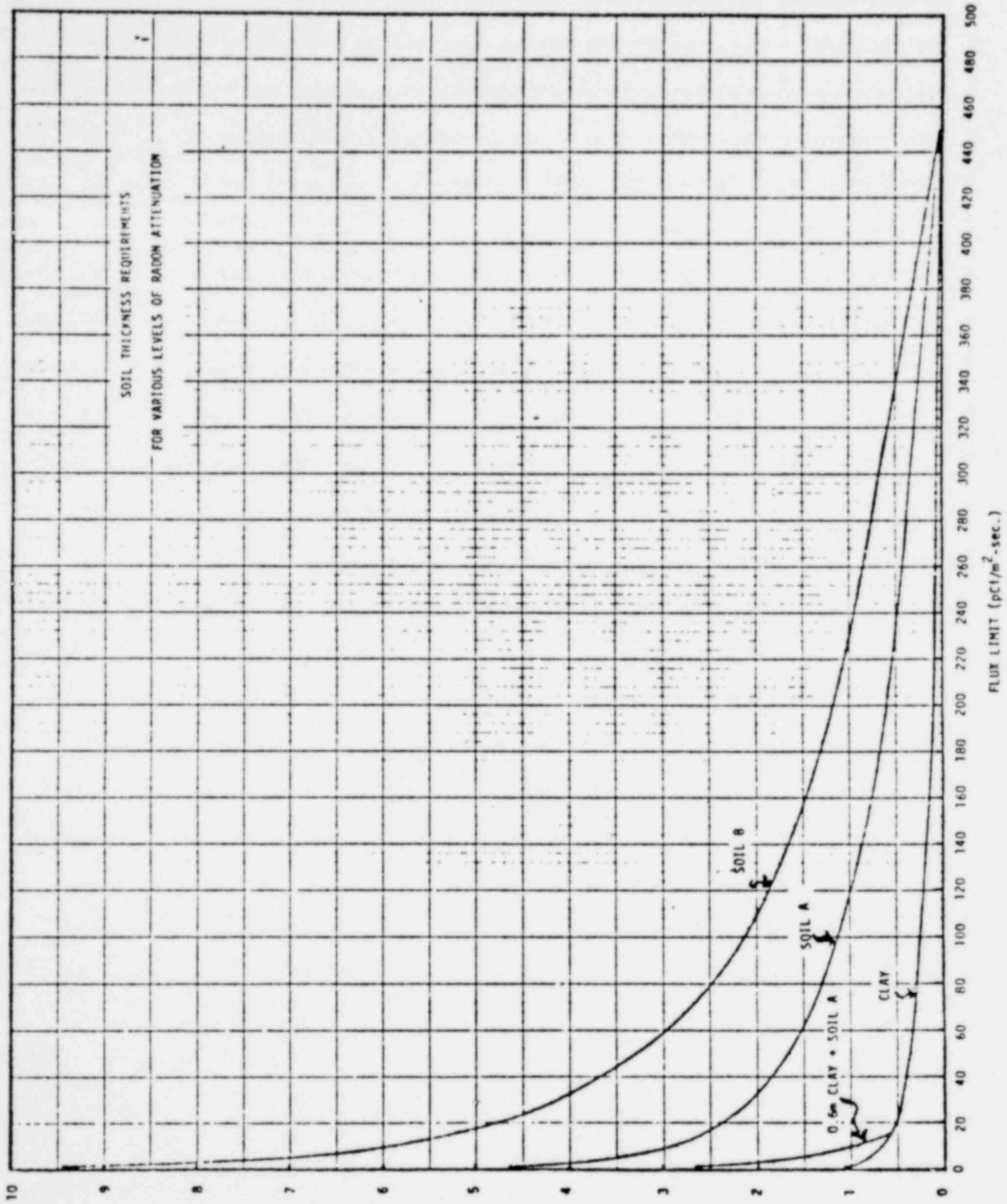
---

(1) Calculated from Equation 1 on page 9-24 and permeability factors from Figure 9.1, page 9-25. (GEIS)

(2) Total industry cost. Assumes 82.2 mills at 800,000 meters^2 per mill and a cost of $1.30 per cubic meter for cover.

(3) Flux of 15.3 pCi/m^2-sec. emerging from 0.6 meters of clay used as J_0 in flux equation of note 1 above for this case. The first cost figures shown are for the 0.6 meters clay and 0.32 meters soil A needed to reach a flux of 10 pCi/m^2-sec.

(4) Ind. Cost = Industry Cost.


SOIL THICKNESS REQUIREMENTS
FOR VARIOUS LEVELS OF RADON ATTENUATION
SOIL B
SOIL A
CLAY
0.6m CLAY + SOIL A
FLUX LIMIT (pCi/m^2-sec.)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
500
TOTAL THICKNESS OF COVER (Meters)
0
1
2
3
4
5
6
7
8
9
10

1.19

FIGURE 2

TABLE XII

REALISTIC ASSUMPTION - VARIOUS COVER REQUIREMENTS FOR RADON FLUX ATTENUATION

Flux Limit (pCi/m^2-sec.)	Soil A Depth[1] Req'd. (m)	Soil A Total[2] Ind. Cost(4) ($MM)	Soil A Incremental Ind. Cost(4) ($MM)	Soil B Depth[1] Req'd. (m)	Soil B Total[2] Ind. Cost(4) ($MM)	Soil B Incremental Ind. Cost(4) ($MM)	Clay Depth[1] Req'd. (m)	Clay Total[2] Ind. Cost(4) ($MM)	Clay Incremental Ind. Cost(4) ($MM)	0.6m Clay + Soil A Depth[1] Req'd. (m)	0.6m Clay + Soil A Total[2] Ind. Cost(4) ($MM)	0.6m Clay + Soil A Incremental Ind. Cost(4) ($MM)
250	0	0	-	0	0	-	0	0	-	0	0	-
100	0.69	72	72	1.41	147	147	0.16	17	17	-	-	-
50	1.22	127	55	2.48	258	111	0.29	30	13	-	-	-
30	1.60	166	39	3.27	340	82	0.38	40	10	-	-	-
10	2.43	253	86	4.97	517	177	0.57	59	19	-	-	-
5	2.96	308	55	6.04	628	111	0.69	72	13	1.00(5)	104	104
3	3.34	347	39	6.82	709	81	0.78	81	9	1.39	145	41
2	3.65	380	33	7.45	775	66	0.86	89	8	1.09	176	31
1	4.17	434	54	8.59	893	119	0.98	102	13	2.21	230	54

---

(1) Calculated from Equation 1 on page 9-24 and permeability factors from Figure 9.1, page 9-25. (GEIS)

(2) Total industry cost. Assumes 50 mills at 800,000 meters^2 per mill and a cost of $2.60 per cubic meter for cover.

(3) Flux of 8.5 pCi/m^2-sec. emerging from 0.6 meters of clay used as J_0 in flux equation of note 1 above for this case. The first cost figures shown are for the 0.6 meters clay and 0.4 meters soil A needed to reach a flux of 5 pCi/m^2-sec.

(4) Ind. Cost = Industry cost in millions of dollars.

(5) 8.5 pCi/m^2-sec. = 0.6 meters of clay at a total and incremental cost of $62.4 MM.

The GEIS values of incremental cover costs to achieve each increment in flux reduction from Table XI have been combined with the corresponding GEIS incremental health effects from Table IX to give the incremental cost per health effect averted shown in Table XIII. Integration periods of one hundred and a thousand years have been included. The results of similar calculations based on adjusted Continental health effects and the adjusted incremental cover costs from Table XII(1) are summarized in Table XIV.

Comparisons of Cost-Effectiveness

The results for the 100 year integration period based on the GEIS values are shown as a function of flux limit in Figure 3 using rectangular coordinates. As would be expected, the more effective the cover, the lower the level it is reasonable to reach. It is also evident that costs begin to escalate rapidly in the 5 to 20 pCi/m^2-sec. range depending on the quality of the cover available. A 2 pCi/m^2-sec. level is far into the region of diminishing cost effectiveness for all types of cover with costs in the range of 8-25 million dollars per health effect averted. Since the curves for the other integration periods will have the same relative shapes, they lead to the same basic conclusion, i.e. 2 pCi/m^2-sec. is well into the range where cost effectiveness is poor.

With the AMC adjusted values (Table XIV) the incremental cost per health effect values move up rapidly for all levels of flux examined. A marked change in slope is indicated at approximately 80 pCi/m^2-sec. for Soil A and would occur at some point greater than a flux of 100 pCi/m^2-sec. for Soil B.

The GEIS proposes to specify both a maximum flux limit of 2 pCi/m^2-sec. and a minimum depth of cover of 3 meters. The interrelationship between these two variables and cost-effectiveness is shown in Figure 4 for the values based

---

(1) At a flux of 250 pCi/m^2-sec. the Continental health effects are

$$\left(\frac{250}{450}\right)\left(\frac{50}{82}\right)\left(\frac{1}{10}\right)(9.7) = 0.33/\text{year}$$

Effects at other flux levels obtained by ratio.

on the GEIS. The ordinate is the incremental cost per health effect averted (log scale) and the abcissa is the total depth of cover in meters. A solid line is given for each of the three types of cover with the numbers by each point showing the corresponding flux limit in pCi/m^2-sec. The scatter from the linear relationship depicted appears to be largely the effect of rounding. The suggested range of appropriate societal costs of $250,000-$500,000 developed previously is also shown for reference.

For the most effective cover, clay plus Soil A, the 0.6m. of clay specified reduces the flux to about 15 pCi/m^2-sec. and averts nearly 9.5 health effects per year. This leaves only about 0.2 health effects per year for the additional cover to impact upon. Further incremental reductions are thus very small so the incremental cost per health effect curve rises rapidly. For the less efficient covers, Soil A and Soil B, the health effects averted are spread over a wider range of cover depths so the curves increase less rapidly.

Using these values from the GEIS it is evident from the figure that the radon flux level that can be attained at the suggested range of societal costs is strongly dependent on the type of cover available. For the clay plus Soil A a range of 4-7 pCi/m^2-sec. occurs at a total cover of about 1-1/4 meters; for Soil A alone the range is 40-60 pCi/m^2-sec at a depth of 1-1/2 - 2 meters; and for Soil B only 60-100 pCi/m^2-sec can be reached at a cover depth of 2-3 meters.

If the societaly acceptable cost is increased to $1,000,000 per health effect, the attainable levels for the three cover alternatives are 4, 20 and 40 pCi/m^2-sec at depths of 1-1/2, 2-1/2, and 4 meters, respectively. To reach the level of 2 pCi/m^2-sec. recommended by the staff, costs would range from 8 to 24 million dollars per health effect averted, at depths of 2, 4, and 8 meters, respectively (Clay + A, A, B). Even a 1000 year integration period would only reduce the range to 800 thousand to 2.4 million dollars per health effect.

The corresponding values based on the AMC adjustments are shown in Figure 5. Since the number of health effects to be averted are considerably lower than the GEIS values and the costs are double, the cost per health effect shifts up sharply from the levels shown in the previous figure. All of the results are an order of magnitude or more above the suggested range of appropriate societal costs.

On the AMC basis, if clay is available, a flux of 5 pCi/m^2-sec. may be approached but only at a cost per health effect around 3 million dollars. If clay is not available, it will be difficult and not cost-effective to reach flux limits below 100 pCi/m^2-sec. Values for 2 pCi/m^2-sec. are off-scale and range from 220 to 470 million dollars per health effect averted. One thousand year integration reduces these to 22-47 million dollars.

Conclusions

The GEIS estimates shown in Figure 4 demonstrate, and the AMC estimates in Figure 5 emphasize that large expenditures of societal resources to reduce radon flux from tailings piles to very low levels is neither cost-effective nor reasonable. There are many more effective ways to reduce societal risks. These results also show that the inflexible level of 2 pCi/m^2-sec. suggested by the GEIS is grossly inappropriate. The need for a flexible range, on the order of 10-100 pCi/m^2-sec., with strong consideration of site-specific conditions is clearly demonstrated.

TABLE XIII

INCREMENTAL COST PER HEALTH EFFECT AVERTED(1) BY RADON FLUX ATTENUATION

Flux Limit (pCi/m^2-sec.)	Depth of Cover (Meters)	Annual(2) Incremental Health Effects Averted (per year)	Soil A		
			Incremental(3) Cost ($MM)	100 Year Integration ($/Health Effect)	1000 Year Integration ($/Health Effect)
100	1.14	7.57	98	129,000	12,900
50	1.66	1.06	44	415,100	41,510
10	2.88	0.86	104	1,209,000	120,900
5	3.40	0.106	45	4,245,000	424,500
3	3.79	0.043	33	5,200,000	520,000
2	4.09	0.022	26	11,820,000	1,182,000
1	4.62	0.021	45	21,420,000	2,142,000

Flux Limit (pCi/m^2-sec.)	Depth of Cover (Meters)	Annual(2) Incremental Health Effects Averted (per year)	Soil B		
			Incremental(3) Cost ($MM)	100 Year Integration ($/Health Effect)	1000 Year Integration ($/Health Effect)
100	2.32	7.57	199	261,800	26,180
50	3.31	1.06	91	858,500	85,850
10	5.87	0.86	212	2,465,000	246,500
5	6.94	0.106	91	8,585,000	858,500
3	7.73	0.043	68	10,600,000	1,600,000
2	8.36	0.022	54	24,550,000	2,455,000
1	9.42	0.021	90	42,860,000	4,286,000

Flux Limit (pCi/m^2-sec.)	Depth of Cover (Meters)	Annual(2) Incremental Health Effects Averted (per year)	0.6 Meters Clay + Soil A		
			Incremental(3) Cost ($MM)	100 Year Integration ($/Health Effect)	1000 Year Integration ($/Health Effect)
100	-	7.57	-	-	-
50	-	1.06	-	-	-
10	0.92	0.86 (9.5)[4]	79	83,000	8,300
5	1.45	0.106	45	424,500	42,450
3	1.83	0.043	33	5,200,000	520,000
2	2.13	0.022	17	7,773,000	777,300
1	2.66	0.021	53	25,240,000	2,524,000

Somatic effects, Continental basis.

Annual values from Table IX.

From Table XI.

0.6 meters of clay reduces the calculated flux to 15.3 pCi/m^2-sec. The cost shown includes an additional 0.3 meters of soil A and the total incremental health effects averted to the 10 pCi/m^2-sec. of 9.5/year.

TABLE XIV

REALISTIC ASSUMPTION - INCREMENTAL COST PER HEALTH EFFECT AVERTED(1) BY RADON FLUX ATTENUATION

Flux Limit pCi/m^2-sec.)	Depth of Cover (Meters)	Annual(2) Incremental Health Effects Averted (per year)	Soil A		
			Incremental(3) Cost ($MM)	100 Year Integration ($/Health Effect)	1000 Year Integration ($/Health Effect)
250→100	0.69	0.198	72	3,640,000	364,000
50	1.22	0.066	55	8,300,000	830,000
30	1.60	0.026	39	15,000,000	1,500,000
10	2.43	0.027	86	31,900,000	3,190,000
5	2.96	0.0066	55	83,000,000	8,300,000
3	3.34	0.0026	39	150,000,000	15,000,000
2	3.65	0.0014	33	236,000,000	23,600,000
1	4.17	0.0013	54	415,000,000	41,500,000

Flux Limit (pCi/m^2-sec.)	Depth of Cover (Meters)	Annual(2) Incremental Health Effects Averted (per year)	Soil B		
			Incremental(3) Cost ($MM)	100 Year Integration ($/Health Effect)	1000 Year Integration ($/Health Effect)
250→100	1.41	0.198	147	7,400,000	740,000
50	2.48	0.066	111	16,800,000	1,680,000
30	3.27	0.026	82	31,500,000	3,150,000
10	4.97	0.027	177	66,000,000	6,600,000
5	6.04	0.0066	111	168,000,000	16,800,000
3	6.82	0.0026	81	311,000,000	31,100,000
2	7.45	0.0014	66	471,000,000	47,100,000
1	8.59	0.0013	119	915,000,000	91,500,000

Flux Limit pCi/m^2-sec.)	Depth of Cover (Meters)	Annual(2) Incremental Health Effects Averted (per year)	0.6 Meters Clay + Soil A		
			Incremental(3) Cost ($MM)	100 Year Integration ($/Health Effect)	1000 Year Integration ($/Health Effect)
250→100	-	0.198	-	-	-
50	-	0.060	-	-	-
30	-	0.026	-	-	-
10	-	0.027	-	-	-
5	1.00	0.0066 (0.32)	104	3,250,000	325,000
3	1.39	0.0026	41	158,000,000	15,800,000
2	1.69	0.0014	31	221,000,000	22,100,000
1	2.21	0.0013	54	415,000,000	41,500,000

---

(1) Somatic effects, Continental basis.

(2) Base case health effect calculated from the Continental value of 9.7 per year as

$$\left(\frac{250}{450}\right)\left(\frac{50}{82}\right)\left(\frac{1}{10}\right)(9.7) = 0.33 \text{ per year}$$

Base case flux is 250 pCi/m^2-sec. Health effects for other flux levels obtained by ratio.

(3) From Table XII.

(4) 0.6 meters of clay reduces the calculated flux to 8.5 pCi/m^2-sec. The cost shown includes an additional 0.4 meters of Soil A and the total incremental health effects averted to 5 pCi/m^2-sec. of 5.3/year.

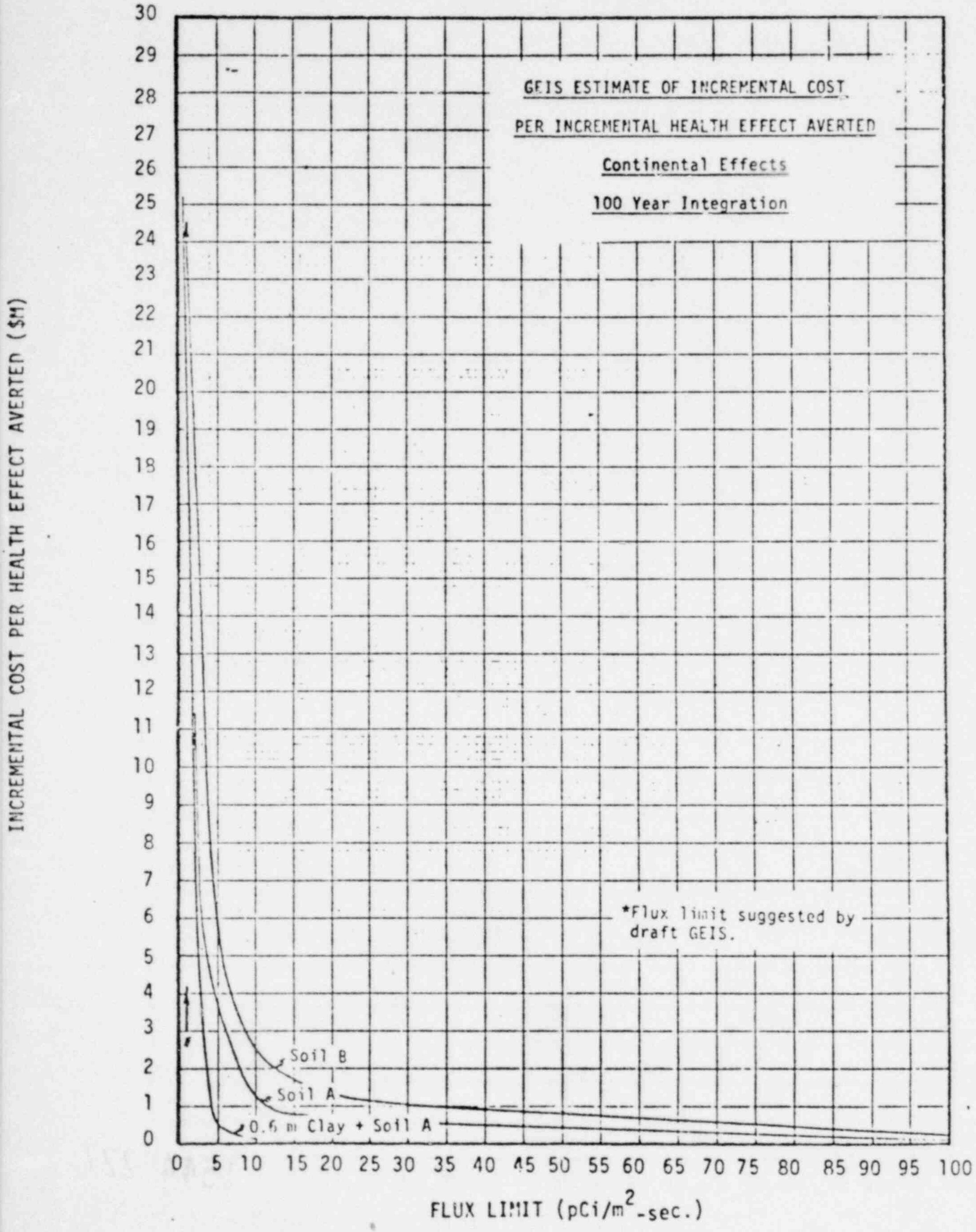

GEIS ESTIMATE OF INCREMENTAL COST
PER INCREMENTAL HEALTH EFFECT AVERTED
Continental Effects
100 Year Integration
*Flux limit suggested by draft GEIS.
Soil B
Soil A
0.6 m Clay + Soil A
INCREMENTAL COST PER HEALTH EFFECT AVERTED ($M)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
FLUX LIMIT (pCi/m^2-sec.)

FIGURE 3

GEIS ESTIMATE OF INCREMENTAL COST
PER INCREMENTAL HEALTH EFFECT AVERTED

Continental Effects 100 Year Integration

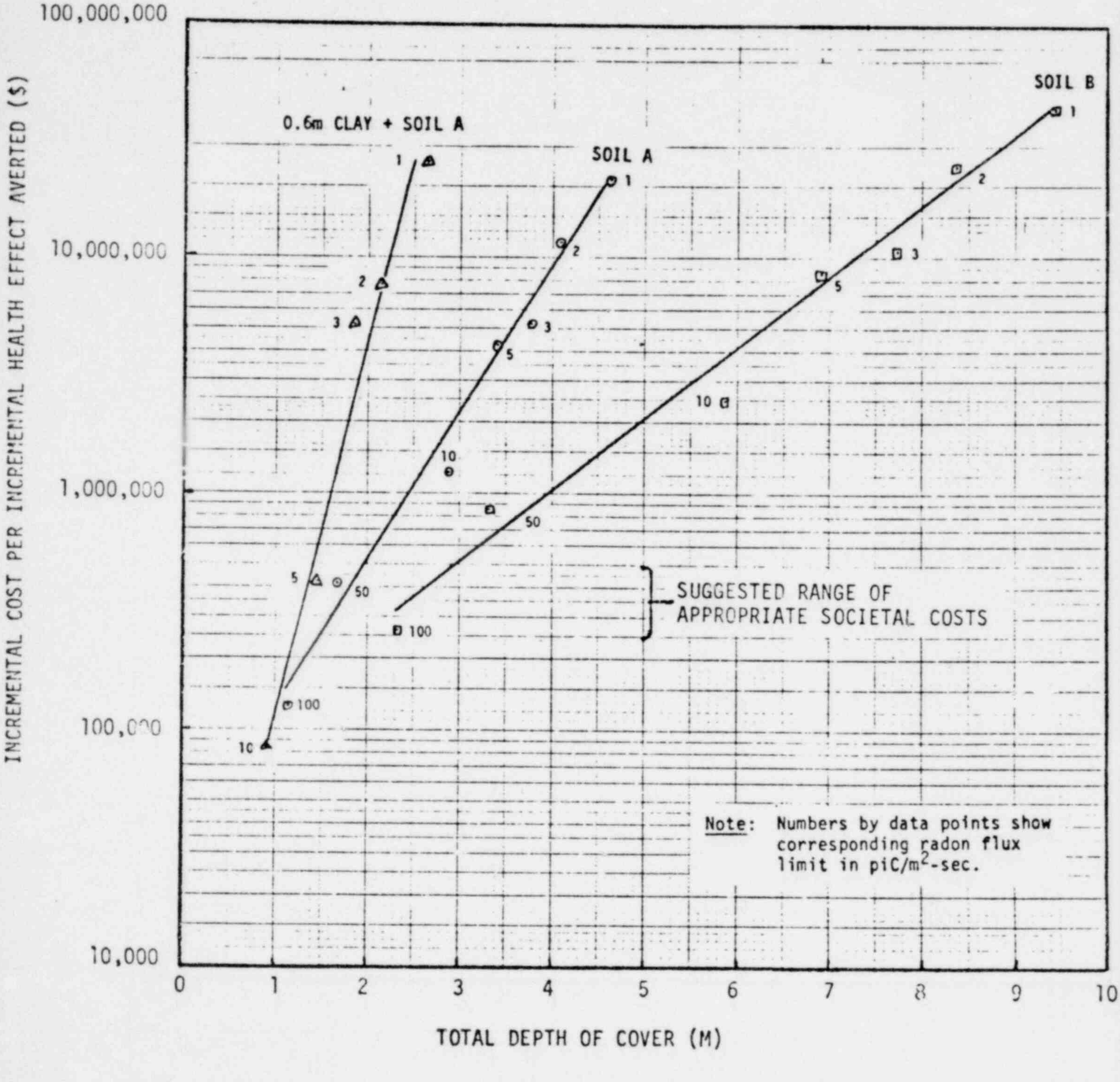
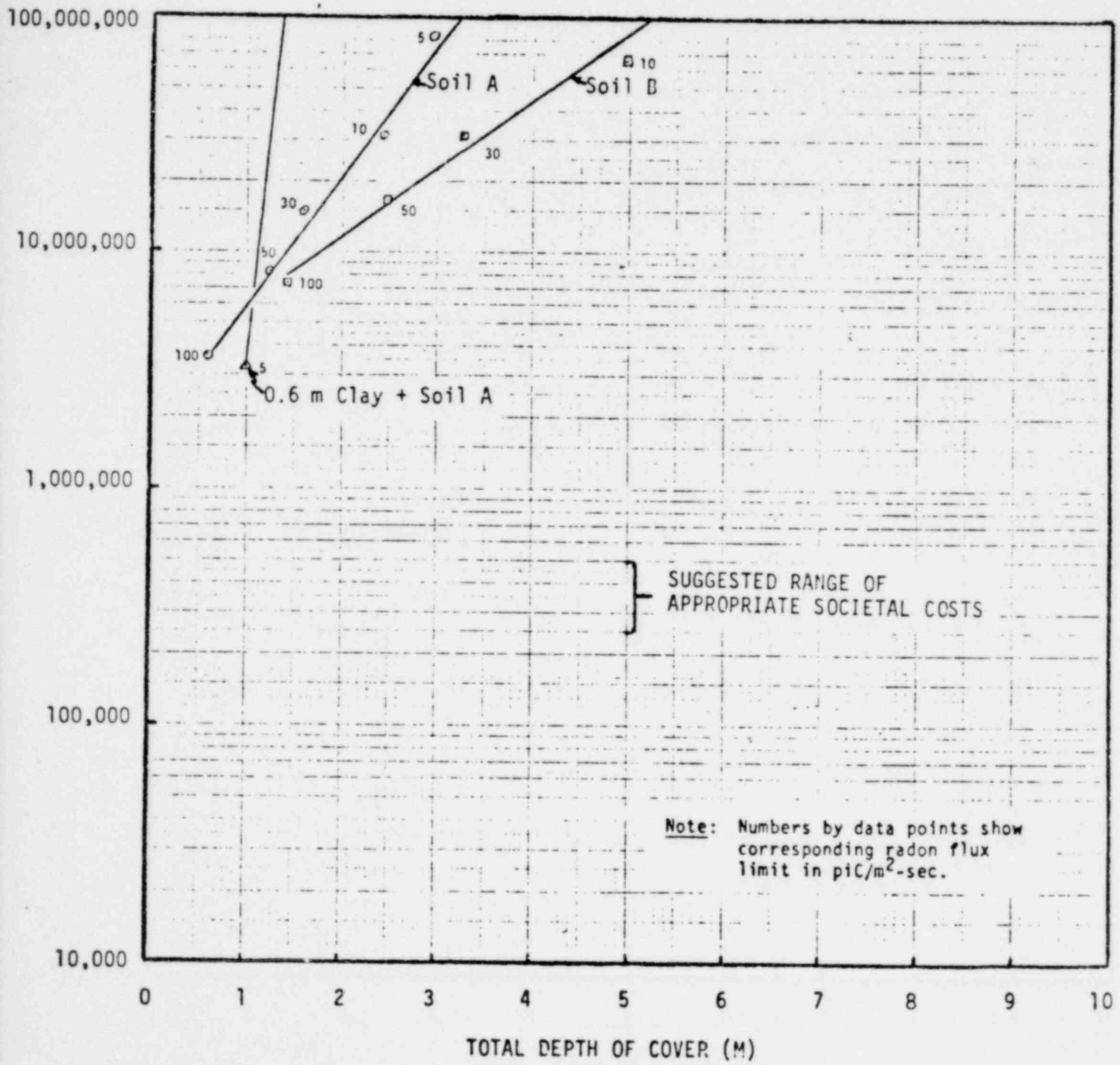


FIGURE 4

AMC ESTIMATE OF INCREMENTAL COST PER INCREMENTAL HEALTH EFFECT AVERTED

Continental Effects 100 Year Integration



Note: Numbers by data points show corresponding radon flux limit in piC/m^2-sec.

FIGURE 5

IMPACT OF NATURAL FORCES AND INTRUSIONS

The previous discussion of cost effectiveness considered only the attainment of certain levels of radon flux. The arbitrary limit of a minimum of 3 meters imposed by the staff as desirable for long term stability and to prevent intrusion would in most cases add materially to the costs. The basis and real value of such added cover with its attendant costs needs to be examined.

Although risk levels have been discussed extensively it is most direct to use the information in Table 5, page 18 of the GEIS to put the magnitude of the problem into perspective.

	Estimated Annual Release (Ci/yr)	Estimated Annual U.S. Population Dose (Organ-rem to bronchial epithelium)	Potential Annual Premature Cancer Death
Natural Soils	120,000,000	16,000,000	1,152
Building Interiors	28,000	22,000,000	1,594
Evapotransiration	8,800,000	1,200,000	86
Soil Tillage	3,100,000	420,000	30
Fertilizer Used 1900-1977)	48,000	6,900	0.50
Reclaimed Land From Phosphate Mining	36,000	4,900	0.35
Totals	132,012,000	39,631,800	2,862.85
Postoperational Releases from tailings			
Base Case	920,000 (0.7)(1)	83,000 (0.2)(1)	6 (0.2)(1)
Proposed Limit	4,000	370	0.026 (0.0009)(1

---

(1) Numbers in parenthesis show percent of total.

It is immediately evident from the table that the risk, even if no covering is applied, on the very conservative GEIS basis is only about 0.2% of that from other common sources of radon. When substantial cover is used a temporary or even permanent failure of a substantial portion of the cover would have an increase in risk that could not be distinquished from the other sources listed.

The staff provides an extensive discussion of general stability, human intrusion, and catastrophic failures of the disposal sites. The general thrust of this analysis is as follows:

Regarding long-term geomorphic changes, page 9-34 states:

> "Climate is a very important driving force and determinant of the rate and direction of the geomorphic proces. . . They do concur that climates are changing and emphasize the profound effect this change, regardless of direction, will have on man's future."

Section 12.6 continues:

> ". . . the very long-term performance of tailings isolation (that is, several thousand years into the future and beyond) will be governed by climatic and geological forces which cannot be predicted precisely. In Section 9.4.1.2 the staff has examined a full range of possible failure modes, not with the purpose of predicting in absolute or quantitative terms changes for or consequences of failure, *but in order to provide a guide in siting and design of tailings disposal schemes*. The pertinent question is *what should* be considered or taken into account *in* order to provide reasonable assurance of long-term isolation of tailings." (Emphasis supplied)

> "However, to account for uncertainties, particularly with regard to very long-term (greater than several thousand years), examining the effects of a certain level of tailings

isolation failure may be useful. Without postulating specific failure scenarios (methods and timing of failure), a "failure" of ten percent of the tailing isolation areas is arbitrarily assumed to provide what the staff consideres to be a very conservative perspective on the matter of potential health effects from radon release. Specifically, it is assumed that there is a complete loss of cover from ten percent of all of the tailings accumulated to the year 2,000. This would result in incremental releases and exposures which are about a factor of 10^{-3} (0.1 percent) of those resulting from natural radon releases (see Table 12-1). Therefore, consequences of such worst case situations are seen to be a very small fraction of those naturally occuring without milling."

"With regard to individual exposures from such "total" failures, no immediate and acute health effects would result. Long and sustained exposure to radioactivity in the tailings pile would be required to produce adverse affects. That is, remedial action would be taken in a time frame that would prevent any adverse health affects to maximally exposed individuals.

"The staff considers that tailings disposal alternatives falling into the "passive monitoring mode" include a strong measure of conservatism in design and siting to assure long-term stability without perpetual active care. However, this analysis shows that the consequences of even several unlikely, "worst case" failures are small in comparison to those occuring from natural releases."

Intrusion and the effect of land use are described with the following general analysis of the magnitude of the problem taken from Section 9.4.2.2, page 9-38.

"Most mining and milling activity occurs in sparsely populated regions. . . . .While recognizing that it is not possible to

> predict climatic and demographic patterns as far into the future as tailings remain hazardous, current conditions and associated very low pressures for land development will most likely continue for a reasonably long period. For this reason, any of the above land use types will tend to be "worst case" or conservative scenarios for evaluating disposal alternatives at most disposal sites."
>
> "A periodic visit to the site (e.g., annually) in addition to either land ownership or records control would provide reasonable assurance that the tailings would remain undisturbed."

And from Section 10.4"

> "As discussed in Section 9.4, because most erosional processes are relatively slow and even the worst of human intrusion events would not result in immediate, acute health effects, the annual inspections would probably be sufficient. Human intrusion or disruptive activities, although extremely unlikely, particularly if there are land ownership controls, could be halted before any health hazard could occur. (Emphasis supplied)

In summary, the staff has looked at long term geomorphic changes and concluded that they are slow, inevitable, and that their direction cannot be predicted. They have also shown that a "very conservative" estimate of the potential amount of complete failure and health consequences of such failure are "a very small fraction of thos occuring without milling."

The problem of human intrusion and its consequences has also been examined. It was concluded that with periodic inspections, the effects of both intrusion and erosion could be halted. The Uranium Mill Tailings Act of 1978 provides for such inspections and the funding to assure that they are performed.

In spite of these conclusions, and although the analysis is described as "a guide in siting and design of tailings disposal schemes", the NRC becomes very specific in their regulatory proposal based on this analysis. A minimum of 3 meters of cover is specified regardless of the flux attained. There does not appear to be any basis for this beyond a desire by the staff to be ultra-conservative and to select a number arbitrarily that fits this concept.

The same problem exists with the selection of below-ground disposal as the prime method of disposal. This is true even if any equally environmentally effective above ground scheme which is more cost-effective is available. It is essential that flexability be retained.

CONCLUSIONS

An extensive examination of the literature on risks in the workplace and risks experienced by the general public was presented. Comparison with occupational risk, with public acceptance of voluntary vs. involuntary risk, and examination of a wide variety of common involuntary risks which appear to be acceptable today suggest that a range of 0.1-ld/m/y is a reasonable approximation of the level of risk that is acceptable to the general public. This range is recommended as a component of regulatory decision-making. It is not intended that it be a rigid rule but a guideline, conditioned by the number of people exposed, the costs to reduce risk, and the general level of societal benefits obtained.

A similar examination of the literature on societal attitudes on expenditures to avert risk suggests that a range of \$250,000-\$500,000 per health effect averted is particularly appropriate to evaluate the cost-effectiveness of the various control measures proposed in the draft GEIS. This, too, would be a guideline, not a rigid rule.

Radon emanation from the mill tailings can persist for many years. This introduces the question of the amount of societal resources that should be used today to avert potential health effects far into the future. Based upon considerations of the impact of a possible cure for cancer and the inability to make long-term predictions of either the geological state of the planet or the conditions and attitudes of society with any degree of reliability, it was concluded that a period of about 100 years was appropriate for use in cost-effectiveness evaluation.

The comparison of the absolute risks to the general public from uranium milling to other risks experienced and found acceptable to society shows that, on a Continental basis, using even the grossly conservative values in the draft GEIS, there is little technical justification for any cover at all on the tailings piles. Examination of risks to the more heavily exposed regional population, i.e. those living within a 50-mile radius of the 12-mill complex, on the GEIS basis, shows that a maximum flux range of 10-100 pCi/m^2-sec. is a reasonable guideline. On the more realistic, but still conservative, AMC basis, there is no strong technical reason to require flux levels below 100 pCi/m^2-sec. The value of 2 pCi/m^2-sec. recommended in the GEIS is totally without support.

Examination of the cost-effectiveness of various levels of radon flux control shows that large expenditures of societal resources to reduce the flux to very low levels is neither cost-effective nor reasonable. The need for a flexible range, on the order of 10-100 pCi/m^2-sec. with strong consideration of site-specific conditions is clearly demonstrated.

The NRC staff provided an extensive discussion of the consequences of tailings cover failure and human intrusion. They concluded that the risks from both of these were extremely small. The AMC agrees with this analysis and concludes that the inflexible requirement of a minimum of 3 meters of cover proposed in the draft GEIS is unnecessary. More flexibility should be allowed.

ATTACHMENTS

Attachment 1

Direct Testimony presented on OSHA Docket No. H-090, Proposed Regulations of Toxic Substances Posing a Potential Occupational Carcinogenic Risk, Dr. Richard Wilson, 1978.*

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* AMC does not necessarily endorse every statement made in this document. We have referenced certain materials from this document in our written and oral comments and it is attached hereto for the reader's convenience.

BEFORE THE

UNITED STATES DEPARTMENT OF LABOR

ASSISTANT SECRETARY OF LABOR FOR

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION

WASHINGTON, D.C.

In Re:)
)
PROPOSED REGULATIONS FOR IDENTIFICATION,)
CLASSIFICATION AND REGULATION OF TOXIC)
SUBSTANCES POSING A POTENTIAL OCCUPATIONAL CARCINOGENIC RISK)
)

OSHA DOCKET
NO. H-090

DIRECT TESTIMONY OF
RICHARD WILSON

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The Concept of Risk

1. Introduction

The principal theme in this testimony is a better definition of the phrase "lowest feasible level" with respect to occupational exposure. Until it is defined, the aim of OSHA of simplifying the hearing process will be nullified. If "lowest feasible level" is to be defined as essentially zero or whatever level is technically possible, then the whole proposal of OSHA is unworkable and it will be attacked in all possible ways. Scientifically, one can reduce almost any exposure without limit--at increasing expense. But we can't afford to spend the whole Gross National Product on one chemical alone.

If, as I propose, the phrase is defined in a common sense manner--and more formally in terms of a risk analysis--then there is a clear working procedure for all parties to follow. I summarize my proposed procedure for risk calculation:

1) Human data should be used whenever possible, but animal data, in at least two different mammalian species, may be used as a surrogate for human data. If animal data in only one mammalian species or mutagenesis data exist and show a very high carcinogenic potency, this can be used to signal an immediate need for more data and the limited data can be used in the interim for limited purposes.

This listing demands slightly more proof of carcinogenicity than that of OSHA's group I. I believe this is appropriate and seems to agree better with recommendations of government committees.

2) We need to know the risk at low exposure levels, and it is hard to obtain statistically significant data at low exposure levels.

Therefore, data at high exposure levels must be used and an interpolation made between these data and the point with zero effects at zero exposure. The preferred technique for simplicity and for a prudent (conservative) public policy is a linear interpolation with no threshold.

3) Data on exposure of humans or animals over a lifetime should be used when possible. When data is only available which covers part of a lifetime, then the risk can be estimated for a full lifetime using a reasonable theory.

4) The cancer risks we ask workers to accept should be comparable to other risks we ask workers to accept and hopefully progressively lower as civilization proceeds. All risks must be reduced, and it is appropriate to reduce the largest risks first, and those risks which are the least costly to reduce. But it is unrealistic to demand that risks due to carcinogens be reduced much more than risks due to other causes.

5) Associated with a linear no threshold theory is usually the statement that at low doses we should measure a long term average exposure to calculate the carcinogenic risk. Fluctuations about this average, while they might affect the actual risk if a threshold is assumed, will not affect the risk if the linear theory is used. This theory remains a conservative upper bound to the risk even in the presence of exposure fluctuations. A more detailed summary of my views on these matters is in reference 1.

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[1] "The Risks of Low Levels of Pollution," Richard Wilson, Yale Journal of Biology and Medicine, Jan/Feb, 1978.

2. The risk/benefit concept

Once it is decided that a chemical is a carcinogen and poses a risk, it remains to decide what to do about it.

It would be nice if it were inexpensive and easy to reduce the exposure to the chemical to such a level that the risk were zero. But life isn't that simple--or at least we cannot prove that it is that simple. As noted later, although there are distinguished scientists who believe that there is a dose below which there is no carcinogenic risk in a human lifetime, there are other scientists who do not; there is no way experimental evidence can directly distinguish the two cases and the argument remains theoretical. However, as noted later, there are few who believe that the cancer incidence is worse than linear with dose, so that a bounding, reasonably conservative, estimate of risk can be made.

If it were possible to reduce all exposure to zero we could reduce all risks to zero. But there are many risks in life--most of them fortunately small--and we cannot reduce all of them to zero simultaneously. We must therefore compare the risks of different actions to cause the same benefits, of different actions to reduce overall risk and then compare the risk and benefit of each action. This is not stated in the OSHA proposal, but it is stated by many advisory boards, including most of those quoted by OSHA in support of the OSHA classification proposal. For example, the National Cancer Advisory Board Subcommittee on Environmental Cancer[2] says:

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[2] "General Criteria for Assessing the Evidence for Carcinogenicity of Chemical Substances: Report of the Subcommittee on Environmental Carcinogenesis," National Cancer Advisory Board, Journal of the National Cancer Inst. 58, 461 (1977).

> "In those cases where a compound has been proved to be carcinogenic, there remains a decision to what extent the possible risks to man are counterbalanced by the possible social, economic, or medical benefits of that substance. Scientists must play a major role in these decisions by providing the available data. The final decision, however, must be made by society at large through informed government regulatory and legislative groups."

In a statement on May 22, 1976, Russell Train,[3] Administrator of EPA said:

> "I believe that it is important to emphasize the two-step nature of the decision-making process with regard to the regulation of a potential carcinogen. Although different EPA statutory authorities have different requirements, in general two decisions must be made with regard to each potential carcinogen. The first decision is whether a parti-Substance constitutes a cancer risk. The second decision is what regulatory action, if any, should be taken to reduce that risk."
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> "In other regulatory areas, for example those under the Clean Air Act, the Federal Water Pollution Control Act, or the Safe Drinking Water Act, where a large number of suspect carcinogens may exist in the atmosphere or public water supplies, the detailed risk benefit assessment will, because of limited Agency resources, necessarily have to be carried out on a priority basis in terms of which agent appears to be the most important."
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> "Once the detailed risk and benefit analyses are available, I must consider the extent of the risk, the benefits conferred by the substance, the availability of substitutes and the costs of control of the substance. On the basis of careful review, *I may determine that the risks are so small or the benefits so great that no action or only limited action is warranted*. Conversely, I may decide that the risks of some or all uses exceed the benefits and that stronger action is essential." (my italics)

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[3] Federal Register, 41102, Tuesday, May 25, 1976.

The first application of the risk/benefit approach was probably in the burgeoning radiation industry in the 1920s. The recommendations of advisory committees in this field are therefore the most sophisticated. A National Academy Committee says:[4]

> "Logically the guidance or standards should be related to risk, whether we regard a risk as acceptable or not depends on how avoidable it is, and to the extent not avoidable, how it compares with the risks of alternative options and those normally accepted by society."
>
> "a) no exposure to ionizing radiation should be permitted without the expectation of a commensurate benefit.
>
> b) the public must be protected from radiation but not to the extent that the degree of protection provided results in a worse hazard for the radiation avoided. Additionally there should not be attempted the reduction of small risks even further at the cost of large sums of money that spent otherwise would clearly produce greater benefit."

The committee goes on to say:

> "When the risk from radiation exposure from a given technological development has been estimated, it is then logical for the decision-making process that comparisons be made and considerations given to (a) benefits to be attained, (b) costs of reducing the risks, or (c) risks of the alternative options including abandonment of the development."[5]

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[4] The effects on populations of exposure to low levels of ionizing radiation. Pages 2-3. Report of the Advisory Committee on Biological Effects of Ionizing Radiation (BEIR) National Academy of Sciences November 1972.

[5] Ibid. Ch. II p. 7. (Needs of the Times)

Dr. Philip Handler, President, National Academy of Sciences introduced a National Academy Symposium on the subject. Among other statements, he makes the following remarks:[6]

> "The burden on the scientific community is to provide adequate basis for such decisions in the future."
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> "The second difficulty lies in the calculus.... in many cases the dimensions on the two sides of the equation are non-equivalent... with dollars on the one side and on the other human lives or less quantifiable social amenities.... But until we settle that question we will be unable to engage in logical decision making in many instances."

In a recent report[7] a World Health Organization group concludes:

> "In those situations where carcinogens are unavoidable, or where the banning of a substance would impose a hardship or an unrealistic economic burden, the toxicologist must assess the risks associated with different levels of exposure."

The fact that carcinogens can vary in their potency by a factor of 10 million--from aflatoxin to saccharin--suggests a graded response to risks. Thus Schneiderman[8] says (and I agree) "materials should be assessed in terms of human risk rather than as safe or unsafe."

Others use the phrase an "acceptable level or risk." Thus Dr. Karybill[9] of the National Cancer Institute says:

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[6] How Safe is Safe?--the design of policy on drugs and food additives. National Academy of Sciences (1974) pp. 3, 4.

[7] "Assessment of the Carcinogenicity and Mutagenicity of Chemicals," WHO Technical Report Series 546 (1974).

[8] "Establishing Cancer Risks to a Population," M.A. Schneiderman and C.C. Brown, Environmental Health Perspectives (1977).

[9] "Pesticide Toxicity and Potential for Cancer: A Proper Perspective," H.F. Kraybill, Pest Control, page 9, Dec. 1975.

> "One should not exhaust one's energy and resourcefulness in the unexorable task of looking for a 'zero' exposure, the 'no effect level' but should view the problem in the context of an 'acceptable level of risk.' This concept should hold for a carcinogenic or noncarcinogenic event."

Sir Edward Pochin, M.D. of the Medical Research Council, devotes a whole paper[10] to discussing risks which society has chosen to accept. Pochin's paper emphasizes that the question of what risks are acceptable is a question for society as a whole: for common man to decide with the facts placed before them in a commonplace way. The scientist can present the facts, his interpretation, and his recommendation based upon what society has decided, implicitly or explicitly in previous situations.

That it is a political decision is emphasized by John Higginson, M.D., Director of the International Agency for Research on Cancer in Lyon, France[11] who warns also that it can be an elitist one:

> "However undesirable, 'political oncology' exists and must be accepted by oncologists and public health officials as a fact of life. Nonetheless perfect environmental control at the expense of the material environment is essentially a concept of the wealthy society. It ill behooves those who have benefited from the industrial society to deny less privileged communities the same material benefits unless the reasons are clear cut and impelling."

In discussing some of the political effects, Higginson goes on to say:

> "the concept of acceptable risk is widely accepted in some form or another."

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[10] E.E. Pochin, Brit. Med. Bull., 31, 184 (1975)

[11] "A Hazardous Society? Individual versus community responsibility in cancer protection," Third Annual B. Rosenhaus Lecture, J. Higginson, Am. Journal Public Health, 66, pp. 361, 363 (1976).

> "In accepting [it] we should be guided by common sense and honesty. We should not subject others knowingly to risks that we would not accept for ourselves or for our families. The decisions on socially acceptable risks which imply the calculation of costs/benefits should not necessarily be confined to an elite group but rather be established through a consensus of society as a whole and/or its respresentatives *assisted by experts.*" (my italics)

The important role of balance in the political decision is stressed by those actually responsible for environmental protection. Thus K. Mellanby, Director of the Monks Wood Experimental Station of the English Nature Conservancy and Editor of the Journal of Environmental Pollution, writes:[12]

> "Some ecologists harm their cause by overstating their case and by condemning any industrial development even if they do not hesitate to make use of the products of that industry! We need to recognize 'real' risks, and to concentrate on eliminating them while at the same time using our technology properly for the benefit of mankind."

One of the advantages of a logical procedure of risk analysis is that it can reduce polarization. John Dunster, Deputy Director General of the (UK government) Health and Safety Executive, says:[13]

> "Some risks are clearly so unacceptable that they must be eliminated. Others, less severe or less likely should be reduced to the point where the benefits of the risky activity balance the costs of the ill effects. Striking the balance invariably involves compromise."

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[12] K. Mellanby, "Unwise Use of Chemicals," Keynote paper in 1st International Conference on the Environmental Future, Finland 1971, p.343, Barnes & Noble, Inc., Ed. N. Polunin

[13] John Dunster, "The Risk Equations, Virtue in Compromise" The New Scientist, 10 May 1977.

We can base an acceptable risk on what is already present. A group of World Health Organization advisors quoted by Truhaut,[14] states:

> "As or where sensitive and reproducible quantitative measures become available, it will be possible to define levels of carcinogens naturally and undeniably present in our environment. From such knowledge it may then be possible to establish 'socially acceptable levels of risk' for carcinogens in the work place and in the general environment."

This suggests an attempt to allow carcinogens if they only add a little to what is already present. For radiation, the internationally regulated tolerance dose is close to the natural background level. But it is possible to do better--to evaluate a risk and to compare the risks. This is the procedure I propose for OSHA.

The Federation of American Scientists, a public interest lobbying group of some distinction, in a report in May 1976, say:

> "There is needed some simple measure of cost and benefit that would make widely different risk situations comparable so as to maintain, in different areas, roughly similar standards for spending government and industrial funds to save lives. Without such a standard, as economists will sense immediately, cancer-avoiding expenditures cannot be spent efficiently. And, in addition the public will have the greatest difficulty distinguishing minimal risks from large ones."

Scientists active in public causes also discuss risk analysis. Barry Commoner[15] points out that it is a societal decision

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[14] "Can Permissible Levels of Carcinogenic Compounds in the Environment Be Envisaged?" Ecotoxicology and Environmental Safety 1, 31 (1977).

[15] "Saccharin and Cancer," Washington Post, Sunday, March 27, 1977.

> "Balancing the benefits against the risks belongs not in the domain of science but to society. The judgment is a value judgment--a social rather than a scientific decision."

Later he says:[16]

> "Based upon widespread concern about health and environment problems the public appears to be ready... to determine what balance between the hazards and benefits is acceptable."

As I look through the scientific literature I find no author who states that a risk comparison is <u>not</u> the way to proceed, although some believe that the "public" is not ready to accept such analyses. Part of this testimony is to show, by comparative analyses, how the facts for decision can be put in a form which is easy to understand so that acceptance is easier.

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[16] Barry Commoner, N.Y. Times Magazine, September 25, 1977, p.73.

3. Risk/benefit analysis

There are several stages to a risk/benefit analysis:

1) The risk must be evaluated. This risk contains two factors: the exposure to the carcinogen, and the carcinogenic effect at this exposure. This will be a simple product *if* it is assumed that the dose-response relationship is linear. The *slope* of this dose-response relationship is the *potency* and we obtain a simple relationship at low doses.

Fractional tumor incidence = potency x exposure and at high doses, since the tumor incidence cannot exceed 100% fractional tumor incidence = 1 -exp [-potency x exposure]. (See Figure 1b later.) The carcinogenic risk *is* the fractional tumor incidence in a large body of people.

Exposure is typically measured in milligrams of pollutant ingested daily or in milligrams per kilogram of body weight when we wish to compare carcinogenic potency between species.

Since the risk, or the fractional tumor incidence, is a number without dimensions, the dimensions of potency are the reciprocal of the dimensions of exposure, or typically 1/(mg ingested daily) or 1/(mg ingested per kilogram body weight). As I will show, this is a conservative estimate (overestimate) of the risk and as such is suitable for a prudent public policy.

2) The benefit of the product must be evaluated.

a. The benefit to society as a whole must exceed the risk. However, the analysis must not stop here. In the 1920's physicians using x-rays for diagnosis correctly argued that the great benefit outweighs the risk. Cautious scientists pointed out that the same benefit can be achieved at much less risk by inexpensive and simple measures (dose reduction, shielding, film sensitizers, etc.) which are now adopted. This makes clear that even if the benefit to society exceeds risk we must still proceed to ask:--

b. Can we obtain the same benefit with less risk by using another chemical or other substitutions. This question is not now within the province of OSHA. Moreover, only if the other chemical is an easy one to use, or a cheap one, is the question simple. Then the question become a subsidiary of questions.

c. Can we reduce the risk at reasonable (to be defined later) expense?

d. Finally, we must ask are the benefits properly disaggregated?--meaning do enough benefits accrue to those directly undertaking the risk? This can, in an extreme case be by compensation or hazard pay.

I will assume that the items 2(a) and 2(b) have already been decided--probably by the marketplace. I will focus on items (c) and (d) in my testimony. A listing of benefits and risks to be considered are in an NAS report[17] from which I take the following table.

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[17] "Principles of Evaluating Chemicals in the Environment," Report of the Committee for the Working Conference on Principles of Protocols for Evaluating Chemicals in the Environment. National Academcy of Sciences, 1975, Chapter III, Benefits.

TABLE I

BENEFITS	RISKS
1 Value to the consumer a) practical utility b) aesthetic value	1 Adverse effect on health a) well being and general health b) death
2 Conservation of natural resources and energy	2 Environmental damage a) air, water, and land pollution b) wildlife c) vegetation d) aesthetic e) property damage
3 Economic a) Employment b) Regional Development c) Balance of Trade	3 Misuse of natural resources and energy sources

Finally, I refer to some summaries of the risk/benefit analysis and its public perception [18, 19, 20, 21, 22] which discuss risk/benefit analysis in other situations.

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[18] W.W, Lawrence, "On Acceptable Risk"Kaufman (1976).

[19] E.M. Clark & A.J. Van Horn, "Risk Benefit Analysis and Public Policy", a Bibliography. Informal report by Energy & Environmental Policy Center, Harvard University for Brookhaven National Laboratory BNL 22285, (1976) (Dec.)

[20] "Perspectives on Benefit-Risk Decision Making," National Academy of Engineering (1972)

[21] A.J. Van Horn and Richard Wilson, "The Status of Risk Benefit Analysis," Informal report by the Energy and Environmental Policy Center, Harvard University for Brookhaven National Laboratory. BNL 22282, Dec. 1976. Printed in Science Policy Implications of DNA Recombinant Molecule Research, Hearings before the House Subcommittee on Science and Technology, U.S. House of Representatives, No. 24, page 751, 1977.

[22] A.J. Van Horn and Richard Wilson, "Factors Influence the Public Perception of Risks to Health and Safety--A Brief Summary Report," Energy and Environmental Policy Center for Brookhaven National Laboratory (1977).

4. Evaluation of the risk--animal and human data

OSHA in the preamble to its October 4, 1977 regulation, spend many pages, citing many authorities, to show that it is necessary to allow animal data alone as a proof of carcinogenesis. This is because it is obviously unacceptable to irradiate humans directly and we want to find out what to do somehow. In many cases where both human data and animal data on carcinogenesis are available (vinyl chloride, radiation) there is moderate agreement--although this is not true of teratogenesis.

I therefore accept the OSHA recommendations that one can accept animal data when human data is unavailable or too inaccurate. Mutagenesis data can also be a useful supplement as a screening test, as I will show later.

I also believe that it is vital to realize that carcinogens vary in their potency and that a mere statement of it is/(is not) a carcinogen is not only unhelpful, but is likely to change as detection sensitivities improve. At the moment this is not recognized in the OSHA proposal.

5. Evaluation of risk--dose-response relationship

The important feature to recognize about a dose-response relationship is that there is one. For example, society used to allow men to work where there were high levels of vinyl chloride in the air--greater than 1 part in 1000 and even up to 10%. Sixty-six cases of liver angiosarcoma have occurred worldwide over 30 years as a result. Now occupational exposures have been reduced a factor of 1000. Will the number of cancers go down by this same factor of 1000 to a level of one cancer in 300 years or more than one in 300 years or less than one in 300 years?

It is only in rare cases that we have data on carcinogenesis in humans suitable for developing a dose-response relationship. But we do know, for example from the work of Doll and Hill,[23] that smoking 40 cigarettes a day gives 10 times the incidence of lung cancer as smoking 4 a day and not smoking at all gives a much lower incidence. This is in agreement with a linear, non-threshold, dose response relationship. For radiation carcinogenesis we also have a linear relationship, with a possible *reduction* at low dose rates. This reduction is, for example, taken into account by the Nuclear Regulatory Commission in their reactor safety report, where further details can be found.[24] There are also indications from a large scale animal test carried out at the National Center for Toxicological

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[23] R. Doll and A.B. Hill, *Brit. Med. J.*, *1*, 1399 (1964). See also, A. Whittemore and B. Altshuler, "Lung Cancer Incidence in Cigarette Smokers. Further analysis of Doll and Hill's data for British Physicians." NYU Medical Center report.

[24] Nuclear Regulatory Commission, Reactor Safety Survey--WASH 1400/ NUREG 73-014, Appendix VI commonly called the "Rasmussen Report."

Research that the dose-response curve for liver cancers is non-linear at low doses.[25] But in most cases, even if data exist to prove human carcinogenesis enough does not exist to establish a clear dose response relation for humans. We must then rely on animal data and analogy.

In the vinyl chloride case, the animal data suggest that the reduction of a factor of 1000 in occupational exposure reduces the death rate by at least a factor of 1000 to a level one cancer in 300 years or less.

The rule proposed by OSHA on October 4, 1977 implies that exposure to any quantity of a carcinogen involves some risk just as a purely linear dose-response relationship would suggest. It is experimentally impossible to disprove such a concept and we are left with only theoretical concepts to guide us. We might envisage three possible relationships between health effects and dose. Fig. 1(a). Proponents of curve A argue in one of two ways. Some argue that the latent period before a tumor occurs increases as the dose decreases, and that when the latent period equals a human lifetime, there is an effective threshold.[26] Others[27] relate the cancer

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[25] Dr. M.F.Cranmer, Presented at the Nov. 28-29, 1977 Science Advisory Committee Meeting.

[26] R. Doll, "Age Distribution of Cancer: Implications for Models of Carcinogenesis," Journ. of Royal Stat. Soc., 134A, 133 (1971).

[27] R.E. Albert and B. Altshuler, "Considerations Relating to the Formulation of Limits for Unavoidable Population Exposures to Environmental Carcinogens," Proceedings of the 12th Annual Hanford Biology Symposium, pp. 231-253 (1972).
"As Assessment of Environmental Carcinogen Risks in Terms of Life Shortening," Environmental Health Perspectives, 13, 91 (1976).
H.B. Jones and A. Grendon, "Analysis of Mathematical Models Used in Data Extrapolation," Clinical Toxicology, 9,791 (1976).
H.O. Hartley and R.L. Sielken, "Estimation of Safe Doses in Carcinogenic Experiments" Biometrics, 33, 1 (1977).

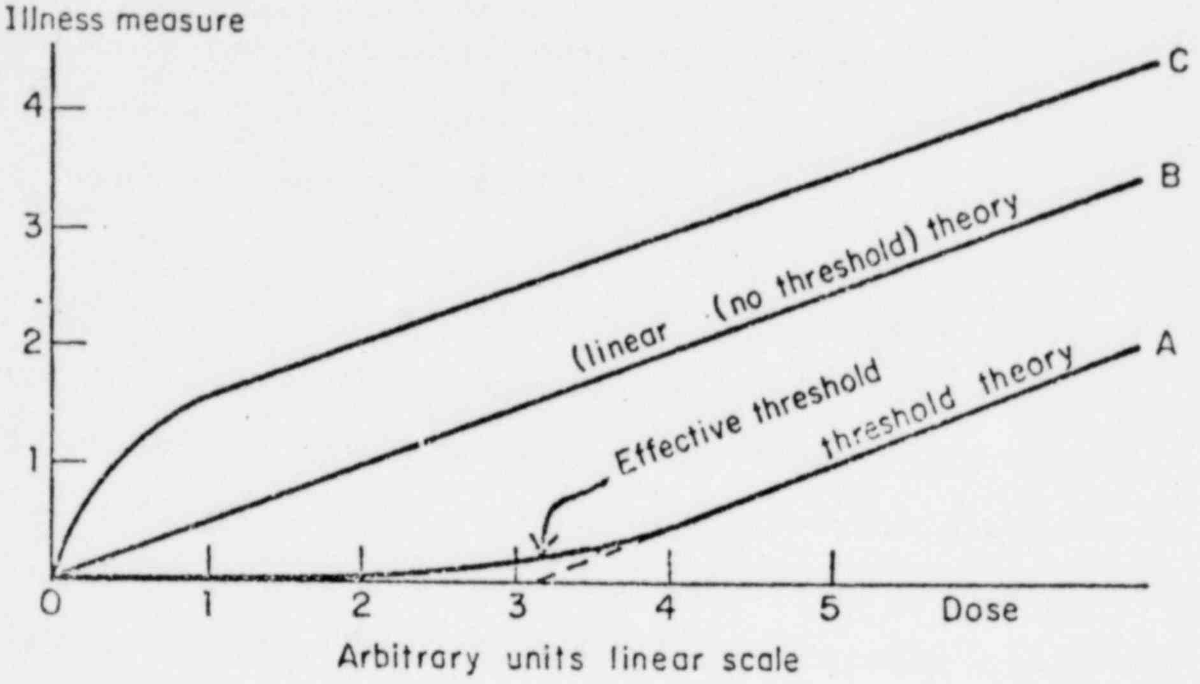
Illness measure
4
3
2
1
0
1
2
3
4
5
Dose
Arbitrary units linear scale
C
B
A
(linear (no threshold) theory
Effective threshold
threshold theory

Fig. 1 (a)

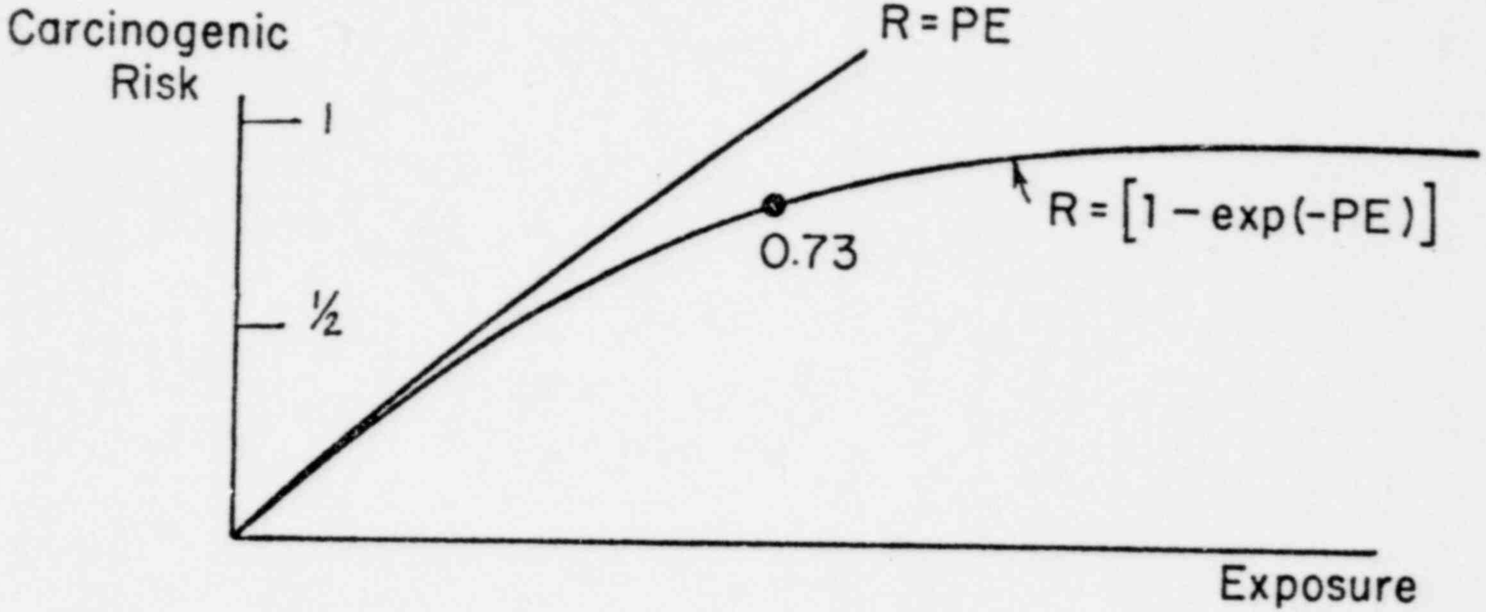

Fig. 1b

induction to some mechanism which implies a threshold. (Curve B comes from the "one hit" theory that the probability of a cancer is random and proportional to the total chemical insult.[28])

The important point, however, is that there is no widespread view that curve C is probable and in this sense the linear, no threshold curve B represents a conservative (pessimistic) hypothetical calculation. It is recommended by many government advisory committees[29] and academic scientists.

I believe curve B should be used for a conservative risk estimation. There should be no need for other safety factors in a risk estimation. It has a further major advantage (as noted earlier)--the ease of simple calculation and simple comparison with other risks.

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[28] P.J. Gehring and G.E. Blau, "Mechanisms of Carcinogenesis--Dose-Response," Journ. for Env. Path. and Toxicology, 1, 163 (1977). R. Olson, Hearings before the U.S. Department of Labor, OSHA, In Re Proposed Standard for Occupational Exposure to Benzene, OSHA Docket No. H-59 (1977) (Direct Testimony).

[29] International Commission on Radiological Protection, (ICRP), publications 3-10, Pergamon Press, London, Oxford and New York.
"The Effects on Population of Exposure to Low Levels of Ionizing Radiation," Report of the Advisory Committee on the Biological Effects of Ionizing Radiation, National Academy of Sciences, November 1972.
"Pest Control, An Assessment of Present and Alternative Technologies," Report of the Consultive Panel on Health Hazards of Chemical Pesticides, Environmental Studies Board, National Academy of Sciences, 1975.
"Estimation of Risks of Irreversibly Delayed Toxicity," D.G. Hoel, D.W. Gaylor, R.L. Kirschstein, U. Saffiotte, M.A. Schneiderman, Journ. Toxicity and Env. Health, 1, 133 (1975).

There may be one or two cases already where the mechanism of carcinogenesis is such that use of a non-linear relationship can be clearly justified; more may appear as more research is conducted. Presumably these could be specifically argued.

It is perhaps interesting to note that this linear hypothesis seems to fit air pollution data[30] and also it is noted by the WHO[31] that incidence of cirrhosis of the liver is directly proportional to the alcohol intake in the country (with a correlation coefficient of 0.93 based on 14 countries with average annual intake varying from 4 to 25 liters per capita).

At low exposure levels the probability of any one person getting cancer in a lifetime is small. Associated with the concept of a linear, non-threshold (or proportional) theory, is the idea that at low doses the important parameter is the dose averaged over a long period of time. Calculation of occupational risks must take this into account.

I note that there is another popular interpolation procedure due to Mantel and Bryan.[32] This relies on a "log normal" distribution and falls between my curves A and B. This fits data as well or better than the linear-non threshold theory. In most cases of interest it leads to a less conservative prediction at low doses. i.e. it suggests a lower cancer risk than the linear theory. For conservative policy the lignar theory is to be preferred.

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[30] Several curves from Norwegian, Japanese and U.S. data are presented in W.J. Jones and Richard Wilson, Energy, Ecology and the Environment, Academic Press, New York, 1974, Chapter VIII.

[31] WHO Chronicle, 1975.

[32] N. Mantel and W.R. Bryan, "Safety Testing of Carcinogenic Agents," J. Nat. Cancer Inst., 27 455 (1961).

6. The risk assessment--specific suggestions

On the rare occasions where good data exists on cancer in humans, such as for cancer caused by cigarette smoking, this should be used for a risk analysis. The dose-response curve of health effect versus long-term average dose should be plotted and a straight line taken from the lowest statistically significant point* to the origin. This can be used as the risk. If a lifetime exposure dose is not known, the data may be corrected to a lifetime cancer incidence using cancer statistics, or if these are not available, using the Weibull formula $dN/dt = \lambda t^k$ which was shown by Armitage and Doll[33] to be a good fit to the age distribution of cancer, with $2 < k < 8$ depending upon the site of the cancer, and λ varying with the geographical location or the environment. For the purposes here, I suggest this formula be used as a useful summary of world cancer data.

Thus, if data exist for people exposed for only the first half of their lives a lifetime incidence for continuous exposure comes by increasing the measured incidence by 2^{k+1}.

If the human data are not statistically significant, reasonable upper limits can still be usefully obtained from the data by drawing a straight line from the top of the statistical error bars to the origin.

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[33] P. Armitage and R. Doll, "The Age Distribution of Cancer and a Multistage Theory of Carcinogenesis," Brit. Journ. of Cancer, 8 1 (1954).
R. Doll, "Age Distribution of Cancer, Implications for Models of Carcinogenesis," Journ. Royal Stat. Soc., 134A, 133 (1971).

* I suggest here that statistically significant be taken as when the random statistical error be less than 1/4 of the value of the point.

If (mammalian) animal data are available, the dose response curve should be plotted to get either a value or an upper limit, as suggested for human data. This then should be related to humans by relating an animal's life (2 years for a rat) to the full human life of 75 years and for equal ratios of the daily food intake divided by the body weight. In some early reports, if 10% of all rats developed cancer in their lifetimes when fed 1 part in 1000 of a carcinogen in their diet, it was assumed that 10% of humans would develop cancer when fed 1 part in 1000 of a carcinogen in their diet. This probably overstates the risk to humans as animals eat a far larger fraction of their weight in food than humans do.

If data on mutagenesis (Ames' test) are available, it should be compared to the animal and human data on carcinogenesis in a plot such as that of Meselson[34] (Figure 2). If mutagenesis data suggest a greater potency (and thereby suggests a larger risk) on this plot it should be used as a signal that the animal data may not be adequate. But I would not recommend that mutagenesis data replace animal data, since there exists carcinogens that are not mutagenic in tests[35] presumably because of inadequate metabolite production, and some mutagens may not be carcinogens.

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[34] M. Meselson and K. Russell, Proc. of the Cold Spring Harbor Conference on Origins of Human Cancer, New York (1977).

[35] "Short-term Screening Tests for Carcinogens," Bryan A. Bridges, Nature, 261, 195 (1976).

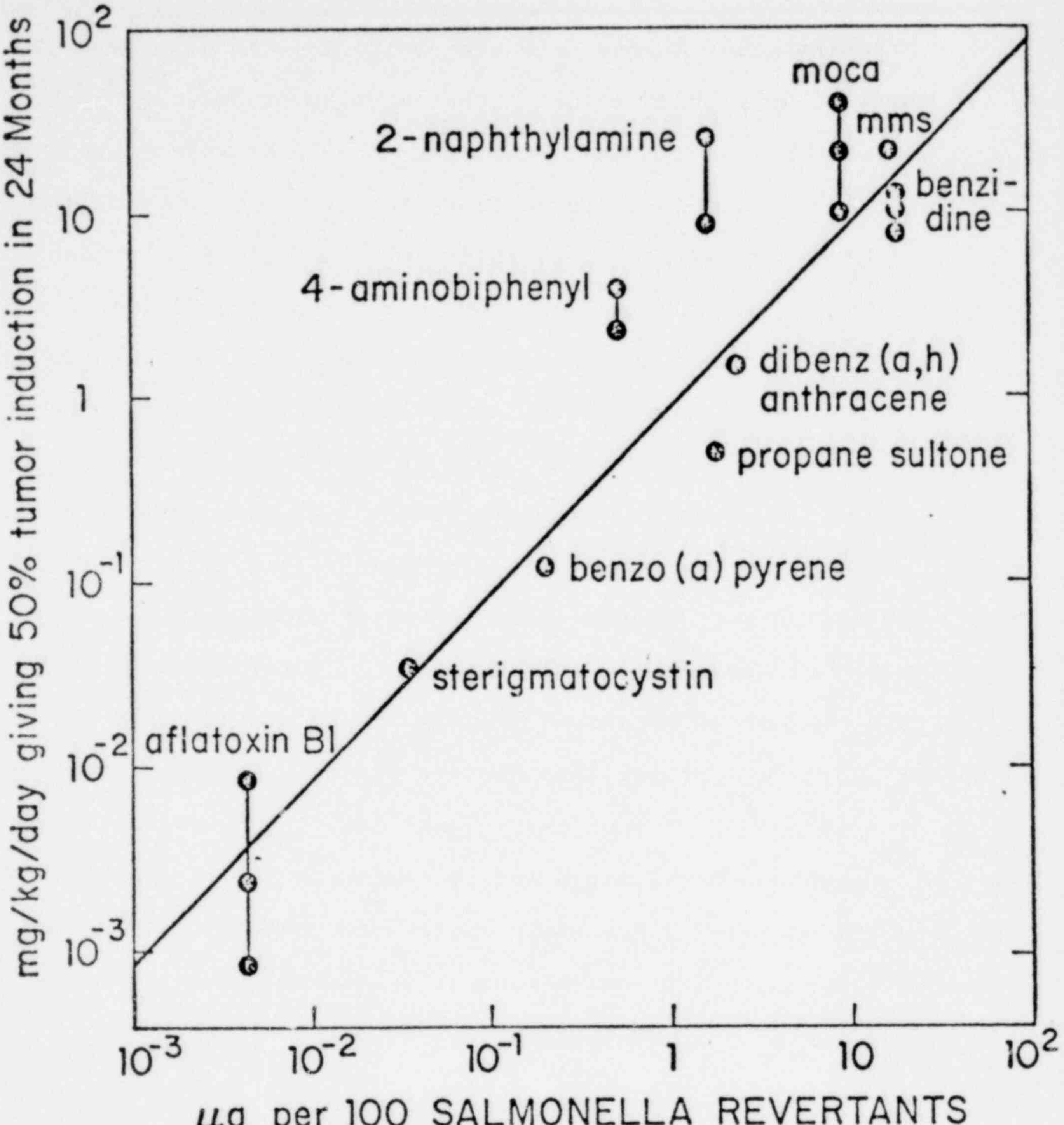
mg/kg/day giving 50% tumor induction in 24 Months
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
moca
mms
2-naphthylamine
benzi-
dine
4-aminobiphenyl
dibenz (a,h)
anthracene
propane sultone
benzo (a) pyrene
sterigmatocystin
aflatoxin B1
10^{-3}
10^{-2}
10^{-1}
1
10
10^2
μg per 100 SALMONELLA REVERTANTS

Fig. 2

Finally, these data can be combined with exposure data (averaged over a long time) to get a conservatively estimated risk.

An excellent discussion of the procedure arises in the discussion of the carcinogenicity of saccharin.[36] I agree with this procedure almost in its entirety.

It is also important to realize that, associated with low levels of pollutant and a linear dose-response relationship, we are interested only in levels of pollutant averaged over a long time--and appreciable fraction of a lifetime. Although there are probably good toxicological reasons for preventing short exposures to very high concentrations of carcinogens, these reasons are not taken account of in this present calculational procedure and must be, and are, dealt with separately, by the ordinary rules and regulations for toxic chemicals.

In calculation of a cancer risk it is important to bear in mind that cancer can appear in sites other than the primary one. This is true of cigarette smoking, where only half the cancers caused are cancers of the lung, and for vinyl chloride where human data suggest that, and animal data show that, only half the cancers are liver angiosarcomas. We know also that, for cigarette smoking, heart disease is also prominent, so for prudent public policy the risk of cancer incidence in the primary site should be multiplied by 4 to get a total risk until other data on risks in the other

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[36] "Saccharin and Its Salts: Proposed Rule and Hearing," 42 Fed. Reg. 19996 (1977).

sites and risk of heart disease are available. Also, as for cigarette smoke, birth defects can be expected.

In order to make a conservative analysis, therefore, I believe it appropriate to multiply the risk, calculated for a cancer at one site only, by 4.

7. Upper limits to a risk

Occasionally the statistical significance of data is not enough to tell us whether the chemical is carcinogenic or not. This may not mean that we know nothing; we can still establish an upper limit to the risk. I illustrate this by the following (hypothetical) example.

Lifetime exposure experiments are performed for a mammalian species at several dose levels; exposure zero (control series); exposure 100 units; 200 unit; 300 units. The data might then look as follows:

Exposure	No. of animals	No. of animals with tumors at end of life
0	500	20
100	500	14
200	500	25
300	500	19

The number of animals (N) with tumors fluctuates by an amount approximately equal to $\sqrt{N}$ which is the fluctuation due to the number of animals used.

I suggest that if the upper limit to the risk comes out less than 1 in 100,000 per year of exposure (10^{-5}/yr) the question can then be ignored by OSHA. If the upper limit comes out to be greater than 10^{-5}, the question of carcinogenicity must be examined further.

This hypothetical set of numbers shows no obvious trend with increasing dose. We can however rule out the postulate that at an exposure level 300 the number of animals with tumor is 35 because this would be about 3 standard deviations from the mean.

I illustrate this by plotting the data graphically. We see that the horizontal line (risk = 0) fits the data quite well, although the fit leaves two out of four points with an error just greater than one standard deviation. The same data can be fitted with a risk line Risk = 10^{-4}/exposure with a stretch of the errors on the control and on the highest exposure point. This gives a probability of less than 1/20, and I take this here as close to an upper limit.

In practice, then, even statistically insignificant data can give an upper limit to carcinogenic potency, which can in turn be put into a risk calculation.

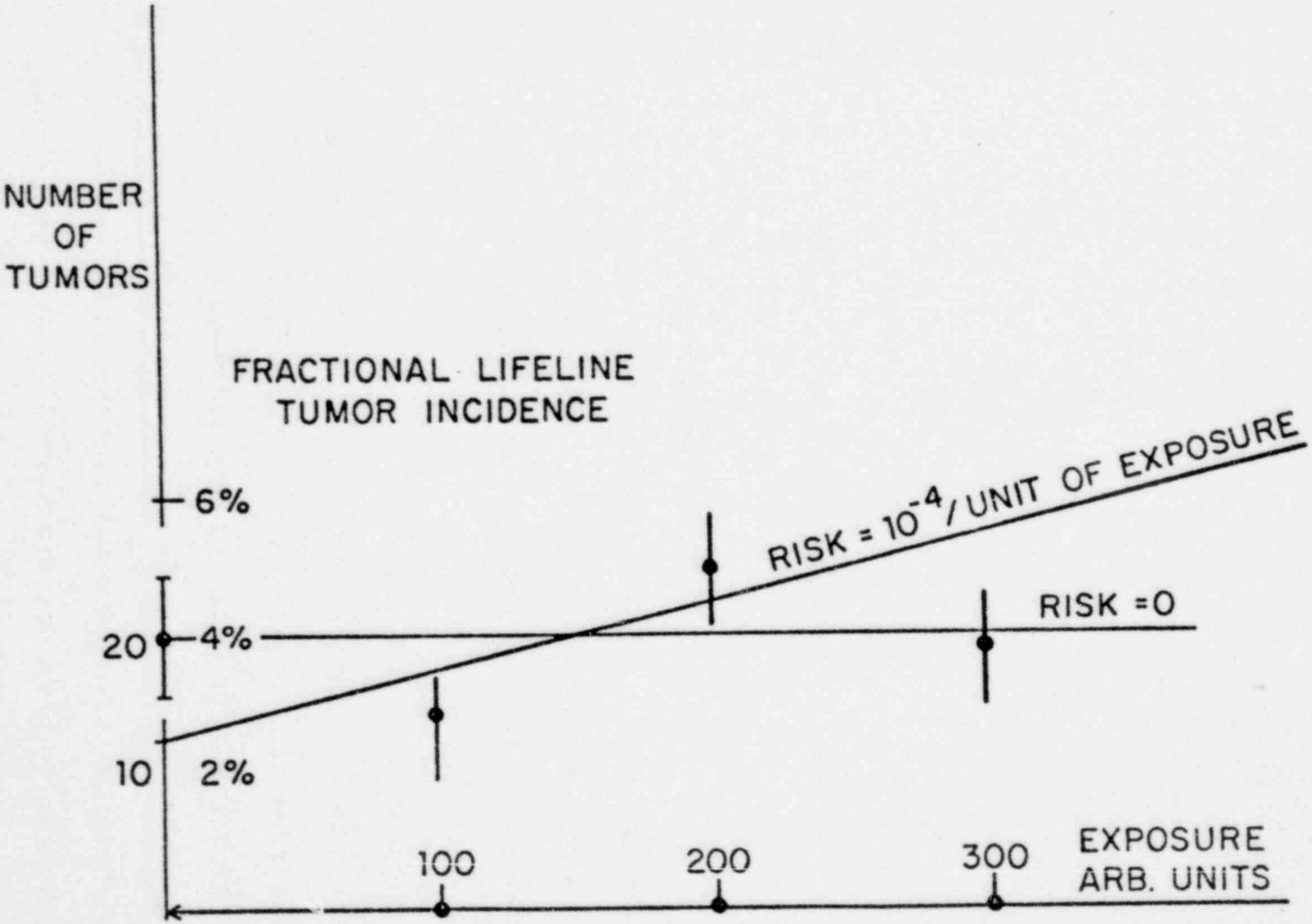
NUMBER
OF
TUMORS
FRACTIONAL LIFELINE
TUMOR INCIDENCE
RISK = 10^{-4}/ UNIT OF EXPOSURE
RISK =0
6%
20
4%
10
2%
100
200
300
EXPOSURE
ARB. UNITS

Figure 3

8. Simplicity and cost of regulation

It is important that a regulation be simple and easy to administer. There are two reasons. Firstly, it will be enforced, and secondly it will not cost too much to enforce.

The linear dose-response relation with no threshold enables risks to be easily calculated and compared. It probably overstates the risk since it assumes there is no threshold, but--unless we insist on the fruitless search for zero risk--this is likely to be less expensive than regulatory hassles over what the threshold, no effect level, or TLV is for the particular chemical.

It is hard to see how to enforce a criterion on the "lowest feasible level" unless a risk assessment of some sort is made. If it is made implicitly, it becomes subjective, rather than objective. One man can argue it is "feasible" to close down one or two industrial plants; another might not. Interminable arguments would ensue on a chemical by chemical basis.

9. The lowest feasible level

I think the course of action suggested by OSHA is inappropriate because it fails to compare risk and benefit.

OSHA, in the proposed rule of October 1977, suggest that the occupational exposure of all chemicals in group I be reduced to the "lowest feasible level." This phrase is not defined, and to the extent it is undefined, it can allow OSHA flexibility in applying common sense to each situation. However, also to the extent it is undefined, it renders the whole stated purpose of the classification--the saving of time in argument--useless.[37] Furthermore, there is a vague indication that "eventually" the exposure should be reduced to zero and to the extent that zero is unmeasurable, this is meaningless and unworkable.

The International Committee on Radiological Protection (ICRP) also made ill-defined recommendations that "no exposure shall be undertaken without expectation of benefit" and that exposures should be reduced "as low as practicable." This committee was, therefore, an early urger of cost benefit calculations. When nuclear power became important, the Atomic Energy Commission (superseded by the Nuclear Regulatory Commission) found it useful to define the phrase

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[37] Debbie Galant writing "Taking Cancer Out of the Workplace," in Environmental Action, a journal of a major lobbying organization, seems to agree. She states: "The problem of determining feasibility may be the clinker in OSHA's cancer policy. A term open to speculation and debate, its vagueness could frustrate the agency's plans."

further and held public hearings over three years.[38, 39]

Likewise, the Environmental Protection Agency is finding problems with enforcement of the ill-defined injunction to use the "best available control technology" and the FDA is struggling with what it means, in these days of sensitive detection methods, to reduce food additives to "undetectable" levels.

I therefore propose that OSHA should define the action to be taken more clearly in terms of risk benefit analysis and for this purpose I suggest a redefinition of category I and a separation of category I into 3 subcategories, (a), (b), and (c), according to the way in which the chemical is used.

Firstly, for all chemicals that are "proven" carcinogens, a risk calculation as outlined above should be mandatory. For new chemicals, or new uses of old chemicals, this should be before the proposed use; for old chemicals, within a stated period --say 5 years--after adoption of the rule.

Secondly, for all chemicals in category I, I would make labeling of risky materials, posting of risky areas and education of workers mandatory. This already happens for one class of workers exposed to carcinogens--radiation workers. It would be an advantage if the procedures were similar between radiation workers and

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[38] The "As low as practicable" hearings, AEC RM-50-1.

[39] The ICRP itself found it useful to change the words. The current form is "all exposures shall be kept as low as reasonably achievable, economic and social factors being taken into account."

chemical workers, because this simplicity would be an aid to understanding. Safety depends on active worker understanding and participation at all levels. An industrial worker can often reduce his risk by his own actions much more easily than his supervisor can. Education and posting of warning signs then would be one of the most important of OSHA actions.

10. Separation of Subcategories

This modified category I can now be separated into its subgroups according to the conservatively estimated risk to the workers. I tentatively propose the following separation and actions to be taken in each group.

Category I(a). Estimated risk of mortality, averaged over a lifetime of continuous work exposure greater than one percent per year (R > 1%/year). In this group steps must immediately be taken to reduce the risk by reducing exposure.

Category I(b). Estimated risk of mortality, averaged over a lifetime of continuous work less than one percent per year but greater than one in one hundred thousand per year (10^{-2}/year > R > 10^{-5}/year). For risks in this region exposure would only be allowed if the cost to reduce them were too great. The cost estimates would no doubt be a subject of discussion between OSHA and industry.

Category I(c). Estimated risk of mortality, averaged over a lifetime of continuous work exposure less than one in one hundred thousand per year (R < 0.00001/year or R < 10^{-5}/year). In these cases the continued worker exposure should be allowed without further question by OSHA at least until other risks are reduced, although OSHA should no doubt continuously monitor the risk, and should probably promulgate maximum exposure levels. Of course, industry might well further reduce the risk without the force of OSHA's regulatory action.

I suggest a figure for the appropriate amount industry should pay for reducing a risk \$10 per person per year for a risk 10^{-5}

per person per year (\$10 for 10^{-5} risk). This corresponds to a cost of \$1,000,000 for every calculated hypothetical life saved. This seems a reasonable number. For example in a plant of 1,000 workers, all of whom are exposed to a cancer risk of 10^{-5}/year, one cancer would be induced every 100 years and if the risk is a hypothetical one and an upper limit there would be none at all. Then to reduce this risk industry should pay \$1 million every 100 years or \$10,000 per year. The Nuclear Regulatory Commission in their discussions of low levels of radiation to the general public (As Low As Practicable Hearing AEC RM-50-1) suggested \$1,000 per man rem of exposure, which corresponds, by a linear, average calculation similar to that suggested here, to \$10,000,000 per calculated hypothetical life saved. They considered this figure to be a temporary figure (pending a large public hearing on the specific subject) and reached it as being a round number larger than any number proposed to them at the hearing. I prefer the lower figure and will make comparisons later in this testimony.

This separation of risk levels is similar to one recently recommended in England by the Royal Commission on Environmental Pollution of the United Kingdom in the 6th Report, 1976. This is shown in Reference 39A, from which I take the attached figure.

Professor J.C. Wood of England writing in his book on industrial law states:[39B]

[39A] W.R. Lee, Brit. Journn. Ind. Med., 34, 274 (1977).

[39B] J.C. Wood, Cooper's Outlines of Industrial Law, 6th Ed., p. 351, Butterworth, London.

"The conduct of any industrial undertaking involves some element of risk to the people employed. An element of danger is something to which in a greater or lesser dedegree, the employees must get accustomed."

From: Ref 39A

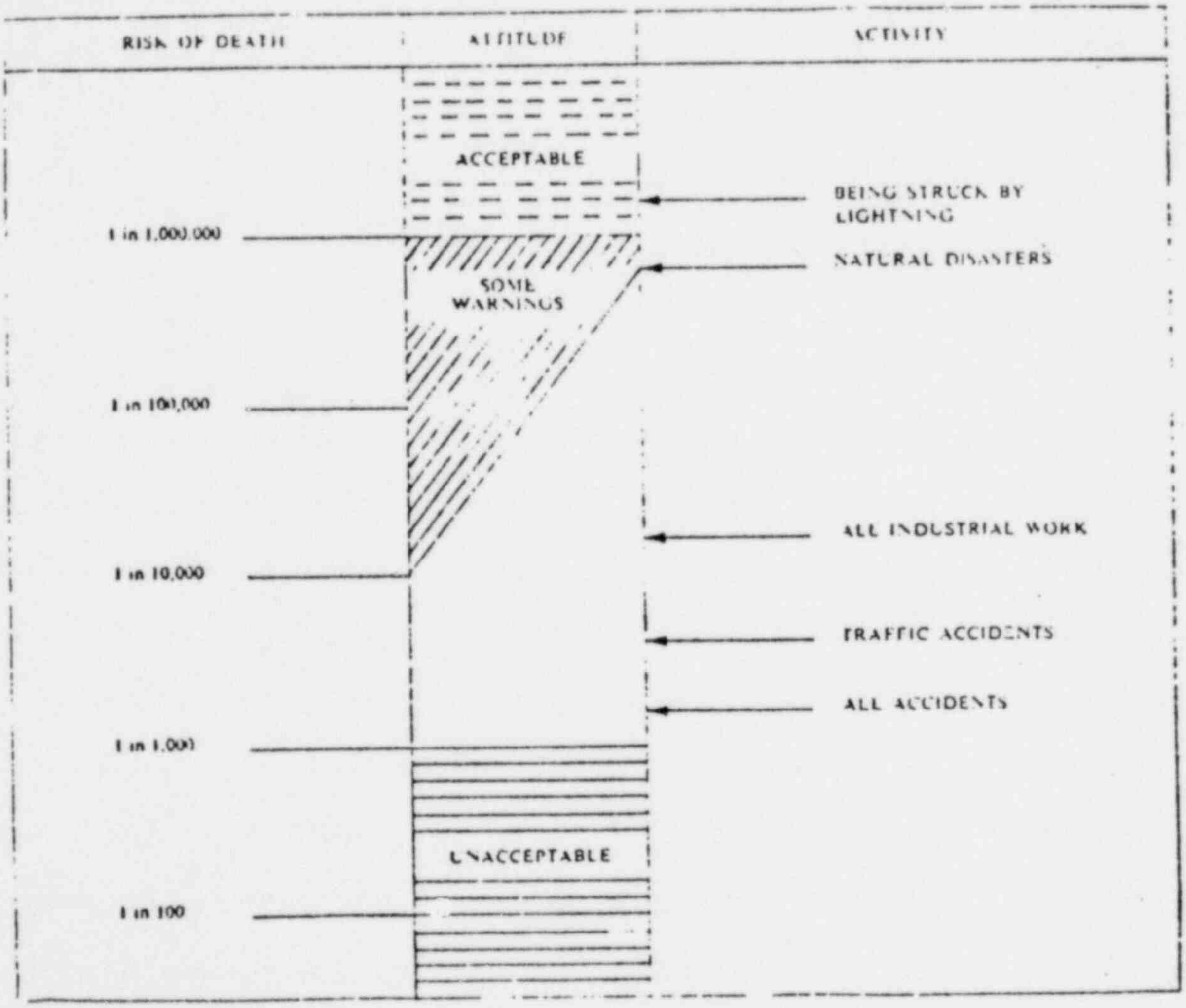

Figure *Probability of death for an individual per year of exposure (orders of magnitude). (Data from Royal Commission on Environmental Pollution, 6th Report, 1976.)*

11. Examples of acceptable risks

As noted above, the acceptability of risks is a political and not a scientific question. I will assume, however, that when properly informed about the risks and their nature the body politic will make sensible decisions. I therefore calculate some risks and show how society in fact accepts many risks. These then are the justification for my suggested limits. I put these in several lists:

1) A list of recreational, voluntary risks (Table II).
2) A set of ordinary involuntary risks (Table III).
3) Since cancer arouses particularly strong emotions, and cancer is the subject of this hearing, I list some cancer risks that are commonplace and presumably accepted (Table IV).
4) A set of occupational risks (Table V).

The recreational risks (Table II) are very hard to quantify because they are so variable. Thus an ardent rock climber will spend more than 40 hours/year in his sport, and be subjected to a higher than average risk. The 100 million bicycles in the U.S. are not ridden with equal enthusiasm. Most people engage in several of these activities--bicycling, sunbathing, fishing, etc. for a recreational risk of 10^{-4}/year; this means that there will be one fatal accident a year for every 10,000 persons engaged in the activity. We watch others, for our enjoyment, who have 20 times larger risks.

Starr[40] pointed out that many of the risks in Table III are voluntary and that people in fact will not accept such large risks if they are involuntary. The table of common non-cancerous risks is mostly involuntary. Purists might insist that driving a car is voluntary (even in the terrible state of U.S. public transportation), but the large risk of being a pedestrian in our car-laden society (4×10^{-5}) is certainly involuntary, and so is urban air pollution.

We come then to the risks of cancer (Table IV). These are separately listed for three reasons. Firstly, an accident leads to an average life shortening of about 30 years[41] whereas black lung disease is an impediment which incapacitates and renders the victim more susceptible to disease but does not kill at once, and cancer also lies latent and kills only late in life. The average life shortening is less--15-20 years. Therefore, the risk might be regarded as less important. The second reason, however, probably outweighs the first. Risks are often perceived by the survivors and not the victims, and the lingering death due to cancer is often more important. Thirdly, many of the cancer risks are uncertain and involve extrapolation to low levels of exposure. These extrapolations are likely to have similar uncertainties (and my cancer risks are probably overestimated as stated in the section

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[40] Starr, Chauncey, Science, 165, 1232 (1969).

[41] Baldewicz, et. al., UCLA-ENG-7485, Nov. 1974.

on dose-response relationships) and comparison is therefore easier.

Finally, the set of occupational risks, Table V, is particularly important because this is an OSHA hearing. Workers have traditionally been allowed a higher risk than the general population. For radiation, for example, the maximum level for occupational exposure is 5 R/year (higher for astronauts) whereas for the general public it is 170 mR/year--one thirtieth of the occupational level.

TABLE II

Risks in Sports[42, 43, 44, 45, 46, 47, 48]

		Deaths 1975	Risk/yr.
Football	Averaged over Participants		4×10^{-5}
Automobile racing			1.2×10^{-3}
Horse racing			1.3×10^{-3}
Motorcycle racing			1.8×10^{-3}
Power boating			1.7×10^{-4}
Boxing (amateur)	40 hrs/yr engaged in sports		2×10^{-5}
Skiing			3×10^{-5}
Canoeing			4×10^{-4}
Rock climbing (U.S.)			10^{-3}
Sunbathing, mountain climbing (skin cancer risk/curable)		300,000 cases	5×10^{-3}
Fishing (drowning)	Averaged over fishing licenses	343	1.0×10^{-5}
Drowning (all recreactional causes) all over U.S.		4110	1.9×10^{-5}
Bicycling (assuming 1 person per bicycle		1000	10^{-5}

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[42] B.G. Ferris, New Eng. J. Med., 268, 430 (1963).

[43] F.D. Sowby, Health Phys., 11, 879 (1965).

[44] C. Starr, Science, 165, 1232 (1969).

[45] K.S. Clarke, J. Am. Med. Assoc., 197, 894 (1966).

[46] Statistical Bulletin, Metropolitan Life Insurance Co., May 1977.

[47] Accident Facts, 1976 edition.

[48] Statistical Abstract of the U.S.

TABLE III

Commonplace and Therefore Accepted Risks of Death (non-cancerous)

		No. of Deaths in 1974	Risk/Year
Motor Vehicle (in 1975)	Total	46,000	2.2×10^{-4}
	Pedestrian (certainly involuntary)	8,600	4×10^{-5}
Home Accidents (1975)		25,500	1.2×10^{-5}
Alcohol--cirrhosis of the liver (1974)			1.6×10^{-4}
Alcohol--cirrhosis of the liver (moderate drinker)			4×10^{-5}
Air travel:	one transcontinental trip/year		3×10^{-6}
	jet flying professor		10^{-4}
Accidental poisoning--	solids and liquids	1,274	6×10^{-6}
	gases and vapors	1,518	7×10^{-6}
Inhalation and ingestion of objects		2,991	1.4×10^{-5}
Electrocution		1,157	5×10^{-6}
Falls		16,339	7.7×10^{-5}
Tornados	Average over several years	160	5×10^{-7}
Hurricanes		118	4×10^{-7}
Lightning		90	4×10^{-7}
Air pollution (total U.S.) estimate (sulphates)		30,000	1.5×10^{-4}
Air pollution (benzo (α) pyrene) urban U.S.--cancer risk			3×10^{-5}
Vaccination for small pox (per occasion)			3×10^{-6}
Living for one year downstream of a dam (calculated)			5×10^{-5}

Sources: Accident Facts, 1976 Edition
Statistical Abstract of the U.S.
Alcohol--detailed discussion in appendix
Air travel--detailed discussion in appendix
Air pollution--detailed discussion in appendix
Dam failure--UCLA report, UCLA-ENG-7423, Payyaswamy, et. al., March 1974

TABLE IV

Commonplace Risks of Daily Life (Cancer Risks)

	Risk/year
Cosmic ray risks	
One transcontinental flight/year	5×10^{-7}
Airline pilot 50 hrs./mo. @ 35,000 feet	5×10^{-5}
Frequent airline passenger	1.5×10^{-5}
Living in Denver compared to N.Y.	10^{-5}
One summer (4 months) camping at 15,000 feet	10^{-5}
Other radiation risks	
Average U.S. diagnostic medical x-rays	10^{-5}
Increase in risk from living in a brick building (with radioactive bricks) compared to wood	5×10^{-6}
Natural background at sea level	1.5×10^{-5}
Eating and drinking	
One diet soda/day (saccharin)	10^{-5}
Average U.S. saccharin consumption	2×10^{-6}
Four tablespoons peanut butter/day (aflatoxin)	4×10^{-5}
One pint milk per day (aflatoxin)	10^{-5}
Miami or New Orlean drinking water	1.2×10^{-6}
1/2 lb. charcoal broiled steak once a week (cancer risk only; heart attack, etc. additional)	4×10^{-7}
Alcohol--averaged over smokers and non-smokers	5×10^{-5}
Alcohol--light drinker (1 beer/day)	2×10^{-5}
Tobacco	
Smoker, cancer only	1.2×10^{-3}
Smoker, all effects (including heart disease)	3×10^{-3}
Person in room with smoker	10^{-5}
Miscellaneous	
Taking contraceptive pills regularly	2×10^{-5}

Sources: See Appendix I

TABLE V

Current Occupational Risks

	Number of Fatalities (in 1975 unless stated)	Risk/yr.
Mining & Quarrying (accident only)	500	6×10^{-4}
Coal mining - accident (average 1970-74)	180	1.3×10^{-3}
- black lung disease (1969)	1135	8×10^{-3}
Agriculture - total	2100	6×10^{-4}
tractor driver (1 driver/tractor)		1.3×10^{-4}
Trade	1200	6×10^{-4}
Manufacturing	1500	8×10^{-5}
Service	1800	9×10^{-5}
Government	1100	1.1×10^{-4}
Transportation & Utilities	1600	3.3×10^{-4}
Airline Pilot		3×10^{-4}
Truck driver (1 driver/truck)	400	10^{-4}
Jet flying consultant & professor		10^{-4}
Steel worker (accident only) (1969-71)	66	2.8×10^{-4}
Railroad worker (1974) (all accidents excluding grade crossing)	688	1.3×10^{-3}
Fire fighters (1971-72 average)		8×10^{-4}

Source: Accident facts, 1976 Edition, p.23,87.
National Safety Council, 444 N. Michigan Ave., Chicago, Ill., 60611
Also, (coal mining black lung, rail worker, steel worker) W. Baldewicz, et al UCLA-ENG-7485 Nov. 1974)
Airline pilot - see appendix
Statistical Abstract of the U.S., 1976 Ed. Table 1200

12. Justification for levels of risk distinguishing subgroups

Category I(a). There is no risk in my table larger than 10^{-2}. Coal mining risk (black lung plus accident) is close--9.3×10^{-3}. This risk is accepted--but barely so. Society now correctly insists that it be reduced.

It seems reasonable, therefore, to take this figure, and use this as the figure above which society must act. I would also insist on action if the risk for an individual plant or process (as distinct from an industry average) were this high.

Category I(c). As shown in Table V there are many occupations where the risk is one in ten thousand per year (10^{-4}/year) or greater, and neither workers nor society take any particular note of them. There are even some everyday, voluntary, non-occupational risks this large.

I note that according to my suggested distinction between subgroups according to risk, exposure to cigarette smoke in the workplace, whether a factory or an executive office, just comes in category I(b) and demands a study to determine whether the exposure can be reduced at reasonable cost. But a continuous exposure to such cigarette smoke is probably an extreme case--applicable primarily to smoke-filled committee rooms--and for most situations the occupational risk of working with smokers is less than 10^{-5}. If, however, we set the level at which exposure must be reduced (if cost effective) at a risk of 10^{-6}, all smoking in the workplace would have to be banned.

Therefore, I suggest that an occupation ten times safer than many occupations, and as safe as living with smokers, cannot be called a dangerous occupation and I suggest a yearly risk less than 10^{-5}/year as one in which the reduction can be left to industry but that OSHA action would almost inevitably cost more than is justified.

13. Cost for reducing a risk

The important question arises, how much should society pay to reduce a risk and how much is society willing to pay? A lot depends upon how the risk is perceived; is it voluntarily accepted or involuntarily accepted? In a classic paper, Chauncey Starr[49] suggests that the public accept risks voluntarily 100 times as dangerous as the involuntary risks. One of the cheapest ways of reducing a risk is to buy a good seat belt for the car and to use it; buying and using a seat belt corresponds to an expenditure of \$5,000 per life saved.[50] People find seat belts inconvenient to use so that only 20% of Americans use them; the mandatory installation of airbags is suggested. An airbag costs about \$100 when installed initially. The total expenditure in the U.S. is then about \$1 billion per year assuming 10 million new cars per year. They would probably save 10,000 lives a year, leading to a cost of \$100,000 per life saved. This still seems cheap, but some people still object to their use. For involuntary risks, costs of \$1,000,000 and more are suggested.

In the 1977 OSHA hearing on the proposed emergency standard for benzene, Professor Richard Zeckhauser, using OSHA's own study pointed out that it was a \$1 billion decision, and yet OSHA had not written down a single number about the benefits of the proposed

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[49] Chauncey Starr, Science, 165, 1232 (1969).

[50] Richard Wilson, "Examples in Risk Benefit Analysis," Chemtech, October 1975.

standard.

For the same hearing I made a risk calculation for benzene and showed that on a conservative basis, OSHA was proposing that society spend \$300 million to save one hypothetical life. The budget of the National Institutes of Health is only three times this and even the gross national product is only two trillion dollars so that we can only afford to save 5,000 or 10,000 lives on this basis. Many more occasions than this arise in which lives can be saved and we cannot afford to spend \$300 million for each one. For this reason, I prefer a number closer to \$1 million spent for every hypothetical life saved.

For example, in an industry employing 10,000 people subject to a risk of 10^{-3}/year, 10 people a year would lose their lives and <u>at least</u> \$10 million a year should be spent to reduce this figure.

The Nuclear Regulatory Commission was probably the first regulatory commission in the U.S. to face up to this problem. In a decision after a long three-year hearing[51] the NRC suggested that if exposure to radiation can be reduced at a cost of \$1,000 per man rem it should be. The risk of radiation corresponds according to the numbers in the appendix (and quoted in many other places) to 10^{-4} per man rem. This is calculated on a linear, non-threshold basis. One thousand dollars per man rem corresponds to \$10,000,000 per life saved. The NRC considered this to be a temporary figure and suggested a large, long public hearing probably with other

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[51] Decision of the Commission in the "As Low As Practicable" hearing RM-50-1.

agencies involved, to decide on this number. Meanwhile they chose $1,000 as being a round number larger than any other presented in testimony at the hearing.

The cost of reducing a risk has also been addressed recently by the International Commission on Radiological Protection.[52] In their publication ICRP 22 they discuss the cost for saving a life in terms of their own new unit, the Sv or sievert. Translated into older units, they quote numbers from $10 to $250 per man rem, or with the risk factors I (and they) assume (10^{-2}/Sv = 10^{-4}/man rem) between $100,000 and $2,500,000 per life saved (conservatively calculated).

My figure of $1,000,000 falls near the top of this.

Another way of looking at the same problem is to realize that if money must be spent on control equipment, lives will be lost in the process. These are secondary effects of the decision process. It is a well known feature of a decision process that if the primary effects are small, the secondary effects must be carefully examined however hard that may be.

Thus, about half of any expenditure on reducing occupational exposure might be expected to be on capital equipment--often construction equipment. In construction work, people die in all sorts of accidents from bulldozer accidents to falling off roofs. The oft quoted example is that three people died in building the Brooklyn Bridge. The total number of workers killed in construction work in the U.S. was 2,200 in 1975.[53]

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[52] International Commission on Radiological Protection, (ICRP) reports ICRP 22, ICRP 26, Pergamon Press, London and New York.

[53] Accident Facts, 1976 ed., p. 23 published by the National Safety Council.

The total receipts of the construction industry were $164 billion in 1972.[54] But this contains a great deal of duplication, due to subcontracts, etc. If we assume that this represents $80 billion of primary construction contracts, I derive a number that for every $36 million spent in construction one life will be lost.

Thus, for this secondary effect alone, no expenditure more than $72 million total ($36 million capital) should be made merely to save one hypothetical life, or $72 million a year to save more than 1 life per year, because it will result in a net loss of life in society as a whole, and even in the subset of working men.

My figure of $1,000,000 to save a life may be low; but other distinguished men think it high. Thus, Nobel laureate Joshua Lederberg says:

> "We might be willing to double our health expenditures for 20% improvement in health; this would imply a willingness to invest $400,000 to prevent a death, which is on the high side of present day political judgments."[55]

Indeed, there are many cases in medicine where lives can be saved for $100,000 or less. Artificial kidney cost $30,000, and an intensive care unit often costs only $20,000 per life saved. An average cost of cancer treatment is about $50,000 (in 1977) and saves perhaps 30% of all cases, corresponding to $150,000 per life saved.

It is also useful to try to imagine how we would best spend

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[54] Statistical Abstract of the U.S., Table 1248.

[55] "How Safe is Safe?--The Design of Policy on Drugs and Food Additives," National Academy of Sciences, 1974, p. 68.

money to save lives. One might well spend $1,000,000 on 20 full time police to reduce automobile accidents or a more strict regulation of automobile speed limits, imprisonment or those with a high concentration of alcohol in the blood, and so on. Thus, expenditure of $1 million in Massachusetts alone could probably save 10 lives a year.

As Trevor Kletz pointed out:

> "There is nothing humanitarian in spending lavishly to reduce a hazard because it hit the headlines last week and ignoring the other (hazards)."[56]

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[56] T.A. Kletz, "The Risk Equations: What Risks Should We Run," New Scientist, p. 320, 12 May 1977.

Examples of Procedure

I now go through several examples showing how this procedure would apply to cases past and in process.

14. Example: Benzene

A recent OSHA hearing on a proposed rule for benzene exposure brought forth testimony on its possible carcinogenicity and testimony on comparisons of risks and costs to reduce these risks.

There is doubt whether benzene properly belongs in group I(a) or in group I(b). Carcinogenicity (leukemogenicity) in humans has, it seems, only been related to aplasia of the bone marrow, and therefore could be due entirely to the toxic nature of benzene at high doses, in much the same way way the correlations between alcohol consumption and cancer have been described. Animals exposed to benzene have not developed leukemia except at doses (200 ppm) where the toxic effects are evident.[57] Nonetheless an estimate of a risk can be found, using a conservative linear procedure.

At the exposure level of 10 ppm, previously established as a maximum to avoid the toxic effects, the risk is 3.5×10^{-5}, including possible leukemias, possible other cancers, and even possible heart trouble in analogy with cigarette smoking as suggested earlier in the specific suggestions on calculating cancer risks. This would put it in class I(b) if carcinogenicity is accepted. According to my proposed categorization, this is greater than 1×10^{-5} and thus it would be incumbent on industry to discuss measures to reduce the

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[57] See testimony of myself, Richard Wilson, in the OSHA hearing on the proposed emergency temporary standard for benzene, July 1977.

exposure if these can be done at the cost of less than \$10 per 10^{-5} risk. In fact, the cost according to OSHA's study, is closer to \$300 per 10^{-6} risk (\$300 million for each hypothetical life saved). I assume that OSHA will, in its aim of protecting the worker's interest, tend to produce a smaller number for this than industry would. I will show in later examples how such a large figure would be absurd in other situations.

However, according to my proposed procedure, the OSHA proposed standard of 1 ppm exposure would reduce the risk to below 10^{-5} and no reporting and detailed discussion of costs with OSHA would be necessary, although obviously industry would reduce the risk if it could be done without great expense.

15. Example: Drinking Water

Workers in areas with heavily chlorinated water are exposed to a lot of chloroform, up to 200 μg per liter in Miami and New Orleans.[58] This, through water in drinking fountains, etc., gives in high areas risks of 3 x 10^{-7}/year.[59] This would be an acceptable occupational exposure, and therefore not of concern to OSHA; but as noted below, it should be of concern to EPA and FDA. But if OSHA sets the level of risk at which a risk benefit analysis is demanded at 10^{-7}, it would be necessary to evaluate the risk of any drinking fountain in the workplace.

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[58] "Preliminary Assessment of Suspected Carcinogens in Drinking Water," Report to the U.S. Congress by U.S. Environmental Protection Agency, December 1975.

[59] "Health Effects of Drinking Water," National Academy of Sciences/ National Research Council, May 1977.

16. Example: Vinyl Chloride

In the 1960's workers were exposed to levels of vinyl chloride monomer in the air of 1 part in 100 and in some cases up to 10% for short times. Ten percent is the level of anesthesia and some workers passed out.

At levels of 1 part in 1000 the risk of cancer per year is over 1%. Once the carcinogenicity of vinyl chloride was discovered, there was rightly an outcry and the exposure was reduced--by a factor of 1000. The occupational exposure is now 1 ppm in the air for an 8-hour working day and gives a risk just about 10^{-5}. Reduction this far is.justified, but further reduction would, according to my proposed rules, not be warranted, both because the expense would be too great and the risk is already low. To reduce the occupational level to 1 ppm, and to reduce the environmental exposure to present levels the cost is $80 M/year and $200 M fixed cost, which, amortized at 20% per annum comes to $40 M/yr for a total of $120 M/yr. To reduce this still further will cost more than this $120 M/yr or more than $100 million per life saved.[60]

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[60] Data from Society of the Plastic Industry. A critic might regard these numbers as high, but not 100 times too high.

17. Example: Asbestos

There is a lot of data on occupational exposure to asbestos. I refer to a summary here.[61] For example, I append Table I from this review here. I note that asbestos exposure increased the lung cancer risk a factor of 11 compared with the average risk of smokers and nonsmokers. Thus we have the number of cancers in a group of N asbestos workers (half smoker and half nonsmokers) was 11 times the risk averaged over smokers and nonsmokers times N or 11 times half the risk for a smoker times N or 5 times the risk of a smoker alone. The historical risk due to asbestos was then $5 \times (1.2 \times 10^{-3}/\mathrm{yr})$ for lung cancer alone or $2.5 \times 10^{-2}/\mathrm{yr}$ assuming other cancers and heart disease are also important consequences of asbestos exposure. Therefore, according to my suggested criterion, immediate action would be warranted--as was indeed the case. Unfortunately a reduction of exposure by a factor of 1000--as was possible for vinyl chloride may not be possible for asbestos, and a detailed calculation of cost to reduce the risk is necessary.

It has been suggested that we replace asbestos by fiberglass to eliminate cancers. It has also been suggested that the carcinogenic nature of asbestos is due to the long fibers and fiberglass will have long fibers also. Indeed, when fibers from fiberglass

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[61] Irving J. Selikoff and E. Cuyler Hammond, "Multiple Risk Factors in Environmental Cancer," Ch. 28 in Persons at High Risk of Cancer: An Approach to Cancer Etiology and Control, Ed. J.F. Fraumeni. New York: Academic Press, 1975.

TABLE 1

Expected and observed deaths among 370 New York-New Jersey asbestos insulation workers, January 1, 1963-December 31, 1973, by smoking habits

	Number of men	Person-years of observation	Cause of death					
			Lung cancer					
			Expected[a]	Observed	Ratio	Pleural mesothelioma	Peritoneal mesothelioma	Asbestosis
History of cigarette smoking	283	2,195	4.07	45	11.06	7	14	19
Current smokers	181	1,443	2.48	32	12.09	6	7	12
Ex-smokers	102	752	1.59	13	8.18	1	7	7
No history of cigarette smoking	87	708	1.58	2	1.27	0	7	6
Never smoked	48	409	0.84	0	–	0	5	3
Pipe/cigar only	39	299	0.74	2	2.70	0	2	3

[a] Expected deaths are based upon age-specific white male death rate data of the U.S. National Office of Vital Statistics from 1963-71, disregarding smokings habits. Rates were extrapolated from 1972-73 from rates for 1967-71.

were injected subcutaneously to rats, cancers were caused which were similar to asbestos cancers.[62]

Therefore replacement of one chemical by another must be done with caution and only after it has been established that the net risk will be reduced. The proposed OSHA regulations seem inadequate in this regard; if one chemical is found to be carcinogenic, it must be replaced by another which may not have been studied as carefully.

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[62] M.F. Stanton and C. Wrench, "Mechanism of Mesthelioma Induction With Asbestos and Fibrous Glass, Journal of the National Cancer Institute, 48, 797 1972.
F. Pott, F. Huth, and K-H. Fredricks, "Tumorigenic Effects of Fibrous Dusts in Experimental Animals," Environmental Health Perspectives, [illegible] ([illegible])
[illegible] Stanton, [illegible] A. Tegeris, E. Miller, M. May and E. [illegible] Carcinogenicity of Fibrous Glass--Pleural Response in the Rat in Relation to Fiber Dimension," Journ. Nat. Cancer Inst., 58 [illegible] (1977).

18. Example: Urban or Rural Job Location

The risk of air pollution in the eastern U.S. is normally attributed to high sulphur and particulate levels. The evidence is based on laboratory and epedimiological data.

As shown in the Appendix, I deduce an average risk of death from all causes of air pollution in eastern U.S. of 1.5 x 10^{-4}/year. This is higher than my suggested occupational limit of risk of 10^{-5}/year.

Most of the air pollution risk is not a cancer risk and may not be strictly comparable. But the section on benzo (α) pyrene suggests that in major U.S. cities the hazard can be appreciable. Data from the National Air Surveillance network exist in a few selected cities up to 1970 (apparently discontinued since) gives concentration of 1 to 2 nanograms/m^3 (Worcester, Mass.; Baltimore, Maryland, etc.)[63] and half this indoors. There is then a risk from cancer alone of 10^{-6}/year.

This is not a large occupational risk, but if there is no discrimination among risks we would have to reduce the exposure to the lowest feasible level. What should be considered feasible in such a case? Should industry in Baltimore move to a location with a lower air pollution--such as Hawaii or Maine?

Alternatively industry can help the community to enforce tough air pollution controls.

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[63] "Preferred Standards Path," Report for Polycyclic Organic Matter, U.S. Environmental Protection Agency, Oct. 1974, Table C-1.

Nor would such criteria apply only to industry. It might be ruled, for some reason other than financial that it is unfeasible for an industry to move far from its sources of iron or coal. But this need not apply to our major universities whose functions might be carried out even better in a rural setting.

The variations among employees are so great that it would seem that only a clear cut financial criterion for feasibility of reducing the risk, as I propose, is a workable one.

19. Example: Airline Pilot

As noted, an airline pilot has an occupational risk (death by accident) of 3×10^{-4}. It might be argued it is not a cancer risk and therefore acceptable. But the cancer risk (cosmic rays) alone is 6×10^{-5}/year (see Table IV and Appendix).

Therefore, a reduction, if feasible, of occupational cancer risks below a level of 10^{-5} would lead to changes in the airline industry unless "feasible" includes sensible financial criteria. It is feasible for airplanes to fly at 10,000 feet and reduce the cancer risk (although the accident risk might rise). A stewardess performs a job (high level waitress) which could be considered unnecessary and it is feasible for passengers to serve their own sandwiches or to eat when they land. It is not feasible to add enough shielding (20 feet of lead) to reduce the cosmic ray level, because most airplanes would not then fly.

The number of U.S. air crew at risk is 50,000 persons full-time equivalent. Therefore at least \$15 million per year ($3 \times 10^{-4} \times 50{,}000 \times \$1{,}000{,}000$) should be spent to reduce accidents if they can be reduced to zero. Probably more than this is spent so the airline industry meets my criterion. But if we were to demand \$300 million per life saved (as is the effective demand even for a hypothetical life in the OSHA benzene hearings), the airline industry should spend \$4.5 billion a year to reduce accidents. Probably with expenditures of this magnitude, on air traffic control, blind landing equipment, etc., accidents could indeed be reduced; but it seems obviously an excessive amount.

20. Example: Teacher in Massachusetts

The laws of the Commonwealth of Massachusetts insist that every teacher, in a school or college, be tested for tuberculosis every 3 years. For those who have a positive reaction to a skin test this must be by a chest x-ray. The purpose is not to protect the individual, but to protect society by making sure that the tuberculosis is not transmitted to students. If the chest x-ray is carried out with a reasonably good x-ray set and with reasonably good medical technicians the equivalent whole body dose is about 7 milliroentgens.[64] (Mobile x-ray units used to give doses as high as 1000 millroentgens.) This dose every 3 years becomes 2 milliroentgens/year and the risk is half the cancer risk of a transcontinental flight per year or 3 x 10^{-7} per year.

This is an involuntary risk forced upon me, and one in which I even have to take time and trouble to expose myself. If OSHA were to insist on reduction of all occupational risks greater than 10^{-7}, their regulation would be in immediate conflict with state law compelling me to take this x-ray.

This is clearly a case where society reasonably asks a worker to undertake a risk--albeit a small one--so that society may benefit. That society asks this of me seems reasonable. That society should ask workers to undertake small risks also seems reasonable.

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[64] Measured at Harvard University Health Services by Dr. J. Shapiro at my instigation.

21. Workers in certain dyestuff industries

One of the most important occupational problems has been cancer of the bladder among certain dyestuff workers. The first of these noted was among β napthylamine workers.[64A] As interpreted by Pochin in Table III of reference 10 there was an incidence of 24,000 per million per year or a yearly risk of 2.4×10^{-2}. Benzidine is also a potent carcinogen (carcinogenic potency in animal tests ≃ 0.05 as defined earlier and discussed in reference 34) and in one plant 20/25 developed bladder cancer.[64B]

The lifetime risk is close to unity and the yearly risk ≃0.05. A study of the plant showed no easy way of reducing the risk. The risk was greater than 1%, so according to my prescription the plant should have been shut down and it was and in the U.K. benzidine production is banned.

Although the animal tests reviewed in reference 24 showed liver cancers, bladder cancer showed up in man. The bladder cancers may be attributed to the body excreting the poison. This effect may be an effect of high doses only. At lower doses, the incidence of bladder cancers may fall below the linear relationship.

[64A] R.A. Case, M.E. Hosker, D.B. McDonald and J.T. Pearson, Brit. J. Ind. Med., 11 75 (1954).

[65B] M.R. Zavon, U. Hoegge and Eula Bingham, "Benzidine Exposure as a Cause of Bladder Cancer in Man," Archives of Environmental Health, 27 1, 27 July 1973.

22. Modifications of Procedure for FDA and EPA

The same classification of carcinogens can also be used for the FDA and EPA. However, it is important to realize that the regulatory procedures should be quite different, particularly when it is assumed that there is no absolute threshold below which there is no risk.

It is reasonable, and it has historically been accepted, that workers in their occupation can undertake certain distinct risks which are larger than risks to the general population. However, if every member of the population were to be exposed to each and every occupational risk at the same level as the exposed workers, the total risk would be excessive. Accordingly, society can, and does, aim to reduce the risks to the public to a smaller value.

For example, the International Committee on Radiological Protection (ICRP) set up in 1927 to regulate the burgeoning x-ray industry, sets a standard for occupational exposure (5 R/year), 30 times what they set as acceptable for the general public (170 mr/year). If we take this same factor of 30 between an occupational risk and a public risk an individual risk of 3×10^{-7} and below might be regarded as acceptable for FDA and EPA. I do not want, at this time, to claim that this same factor of 30 between an occupational risk and a public risk should always apply. But some factor seems appropriate.

In a discussion of chemicals--especially di-ethylstilbestrol (DES)--can appear as accidental additives in foodstuffs, the

the Commissioner of FDA (in February 1977) recommended a lifetime risk of 10^{-6} as acceptable--which is a yearly risk of 1.5×10^{-8}. At first sight, this proposal seems inconsistent with mine. However, his procedure for calculating the risk, the Mantel-Bryan extrapolation procedure, is less conservative in most cases than the simpler, and more easily justified, procedure here. The extra factor of conservatism is about the factor of difference. My proposal would give the same result as that of FDA's commissioner in all applications of interest.

23. Suspect Carcinogens: OSHA Category II

It is also possible to use risk analysis techniques when carcinogenisis is only suspected. As cited above, it is not clear, for example, whether benzene should be considered a carcinogen in itself or not; on the assumption that it is, however, I evaluated a conservative risk which suggests that previous regulatory levels for benzene were adequate and conservative even if benzene proves to be a carcinogen.

The crucial feature that enabled me to do this for benzene was the existence of a body of data on persons exposed to benzene at dose levels 10-40 times the previous limits. Animal date at high dose levels also became available after the hearing and gives a conservative upper limit in agreement with the risk from human data.

Therefore, I suggest that upper limits to risk be calculated, wherever possible, on all suspect carcinogens in OSHA's category II. In many of these cases, animal data may not be available, and the cheap and fast mutagenesis data may have to be used to establish a reasonable upper limit.

It seems reasonable to insist that no new occupational exposure to even a suspect carcinogen be allowed unless the upper limit of risk is less tnan 10^{-2} and not this large if it can easily be reduced, although one would not have such a strict criterion as when a definite threshold level of carcinogenesis is known.

Increased use of a new chemical can clearly be allowed as more precise data establish a lower upper limit of risk.

My proposal on suspect carcinogens would avoid a ridiculous situation that can occur with OSHA's proposed rules. If industry propose to manufacture and use a new chemical, it is not allowed unless it is proven to be toxic or carcinogenic. Although the regulatory authorities do insist on some carcinogenesis tests, the regulations provide no incentive to make these tests as sensitive as possible. Indeed, as pointed out by Schneiderman,[65] there is an incentive to make experiments less accurate than possible, because then there is less likelihood of the chemical being proven carcinogenic. Under the proposed procedures, exposure to a proven carcinogen must be reduced to the lowest feasible level--much more severe than for suspect carcinogens. My proposed procedure leads to a much smaller difference between actions for suspect carcinogens and proven carcinogens and indeed provides incentives for good (sensitive) experimentation since upper limits to the risk can then be reduced, and increased exposure allowed, without the fear that a proof of carcinogenesis will cause unnecessarily expensive restrictions.

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[65] M.A. Schneiderman and N. Mantel, "The Delaney Clause and a Scheme for Rewarding Good Experimentation," Preventive Medicine, 2, 165 (1973).
M.A. Schneiderman and N. Mantel, "Estimating Safe Levels--A Hazardous Undertaking," Cancer Research, 35, 1374 (1975).

25. Conclusions

The aim of OSHA in classifying carcinogens is good, although I believe the distinction between categories I and II is not correctly drawn. More important, however, is the discussion of regulatory action. The aim of simplicity and definitiveness is nullifed by the use of the nebulous phrase "to the lowest feasible level." To the extent this phrase is undefined, we are as much up in the air as before. If the phrase is defined to mean zero, or close to zero, the whole OSHA proposal is unworkable. A definite meaning can be defined by means of risk analysis. As soon as risk analysis is accepted the sharp distinction in regulatory action between carcinogens, suspect carcinogens and other hazards, real and potential, vanishes.

I propose that a risk analysis be carried out for all carcinogens and for most suspect carcinogens. If the risk, at the estimated exposure, is less than 10^{-5}, OSHA should take no action. I have shown that if OSHA acts on risks less than this, inconsistencies and absurdities creep in.

APPENDIX

APPENDIX I

Explanation of and Sources for Risk Calculations

I.1. Introduction

It is hard to be as consistent as one would wish about the calculations of risk. In some cases below I have followed my own prescription (aflatoxin) in others I have preferred to take the estimate of a government report or committee where it did not differ widely from my own. This leads to a small inconsistency, and discrepancies between the numbers presented here and numbers I presented in earlier hearings and in publications. The detail below will, I hope, make the reliability of the numbers and the small inconsistencies clear.

I also do not make here detailed least squares fits to the data, but only approximate fits--often graphical. Others can take the data and improve on the risk estimates, but my estimates will not be off by more than 25% from this cause.

I.2. Radiation

Radiation cancers have been studied in humans and animals. I take the numbers here from the Report of the Committee on Biological Effects of Ionizing Radiation (BEIR) of the National Academy of Sciences, November 1972. This uses a linear interpolation for low doses also. Radiation works directly on the cell and avoids problems with toxicity at high dose levels.

There have been tests with over one million mice at the Oak Ridge National Laboratory. These suggest that the effect at low dose rates is 1/4 of that calculated from this linear curve. This reduced the number of cancer cases from background radiation, but probably not the number of cases from diagnostic x-rays or jet airplane flights where the dose is rapid. It is often stated that chemical carcinogens give a smaller insult to each cell than radiation. To this extent we might expect a low dose rate effect to occur for chemicals. The numbers here remain conservative upper limits.

Cross-country airplanes travel at an altitude of 35,000 feet (10 kilometers). At this height there is an appreciable dose due to cosmic radiation, including neutrons. To estimate this, I use the UNSCEAR report.[2] The dose at a latitude of 55°N is 2000

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[1] "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation," Report of the Advisory Committee on the Biological Effects of Ionizing Radiation. (BEIR) National Academy of Sciences/National Research Council, November 1972.

[2] Report of the United National Scientific Committee on the Effects of Atomic Radiation, UN, NY, 1962, page 20[illegible], figure 1. It might be thought that the neutrons would be absorbed by the airplane and the body. Since they are in equilibrium with the surrounding air, this can be allowed for by taking the dose at a lower altitude from the figure. This is a small reduction.

millirems/year of ionizing radiation and 3600 millirems/year of neutrons. This will increase markedly during a period of a solar flare.

Using 365 days a year, a 5 hour flight at 10 km gives a dose between 3 and 4 millirems. Now, using the relationship between cancer incidence and whole body dose in the BEIR report,[59] I find a cancer risk of 5×10^{-7} per transcontinental flight. This is smaller than (1/6 of) the risk of accident and is normally neglected in any discussion of the risks of airplane travel. But it is derived on a comparable basis to the cancer risks discussed here and helps to put them in perspective.

The doses from diagnostic x-rays, from buildings and so on, are obtainable from various places. One of them is the UNSCEAR reports[2] and the BEIR report[1] referred to above. I have also prepared a convenient list.[3] The risks are obtained from the dose list by simple multiplication of the dose and the risk per unit dose in the previous paragraph and reference 1.

I note here that many studies have been made of the radiation levels in buildings and how to reduce them. A lot of the radiation dose comes from inhaling the radioactive gas, radon, which can produce other radium daughters in the lungs. This could be stopped by painting the bricks with epoxy resin. Although obviously

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[3] Chapter IX, R. Wilson and W. Jones, Energy, Ecology, and the Environment, Academic Press, 1974.

TABLE 9-6

Some Typical Radiation Doses*

Source	Dose (mrem/yr)	Radiation cancers/yr if all U.S. population so exposed
Potassium 40 naturally occurring in body	20	1000
Potassium 40 naturally occurring in neighboring body	2	100
Gamma rays from neighboring soil and rocks (av.)	50	2500
Gamma rays inside brick or stone buildings	30-500	1500-24,000
Cosmic rays at Vernon, Vermont	30	2000
Background dose at sea level (av.)	100	5000
Background dose at sea level in Kerala, India (av.)	500-2000	25,000-100,000
Cosmic rays at Denver, Colorado	67	3000
3-hr jet-plane flight	2	100
60 hr/month of jet-plane flight (pilot)	500	24,000
Medical diagnostic X rays in U.K. (av.)	14	1000
Medical diagnostic X rays in U.S. (av.)		
1964	55	2600
1970	95	5000
Weapons tests "fall-out"	3	150
AEC "design criteria" for reactor boundary (upper limits for actual use)	5	250
Within 20-mile boundary of BWR with 1-day hold-up but leaky fuel (gaseous emission) (av.)	0.1	250
Within 20-mile boundary of PWR with leaky fuel (av.)	0.002	0.02
Within 20-mile boundary of coal plant (av.)	0.01	0.1

* Lists such as this can be combined from various general sources: [1, 2, 42, 43, 44, 45, 46, 47].

feasible, it is not cost effective according to my criteria.[3A]

[3A] "Final Report on Study of the Effects of Building Materials on Population Dose Equivalents," Dade W. Moeller, D.W. Underhill, Report by Harvard School of Public Health for U.S. Environmental Protection Agency, December 1976.

I.3. Saccharin

The risk stated in Table IV comes from animal data at high doses and an extrapolation to the known total consumption of saccharin in the U.S. The number here comes from the testimony Dr. Marvin Schneiderman to the Rogers Committee of the U.S. House of Representatives.[4] I have checked his numbers and agree with them. Dr. Schneiderman took the data from a second generation of rats exposed to saccharin. To be wholly consistent with the other date here, we should take first generation data only--then the number should be divided by 3. Dr. Sidney Wolfe, Director of the Health Research Unit, in a press interview, suggested a death rate which corresponds to twice the figure taken here.

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[4] See also Federal Register, April 15, 1977, page 20001.

I.4. Drinking Water

The principal carcinogen in drinking water is chloroform--found to be carcinogenic in both rats and mice.[5] This carcinogen is not produced by chemical industry, but by action of chlorine in water purification systems on organic matter.[6]

A survey of concentrations has been done by EPA[7]. Concentrations of 200 ppm have been found in drinking water of Miami and New Orleans and are taken here. The risk can be calculated directly from the rat and mice data or can be gotten from a National Academy Report.[8] The National Academy of Sciences calculate the risk as 3.7×10^{-7} lifetime risk (upper limit, 95% confidence) for 1 µg/liter concentration in water. Although I originally derived a slightly higher figure I will take their upper limit as a best estimate. This leads to 6×10^{-9}/year for 1 µg/liter or 1.2×10^{-6} for a yearly risk with a level of drinking water of 200 µg/liter, such as we find in Miami and New Orleans. I assume that the NAS calculations refer to ordinary intake of water. The risk is larger in many cases when bromodi-

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[5] "Report on Carcinogenesis Bioassay of Chloroform," National Cancer Institute, 1976.

[6] J. Carroll Morris, Harvard University, "Formation of Halogenated Hydrocarbons by Chlorination--A Review," Report to the Environmental Protection Agency, PB 241511, March 1975.

[7] National Organics Reconaissance Survey Quality Water Data. U.S. Environmental Protection Agency; sheets enclosed.

[8] Drinking Water and Health, Report of the Committee on Safe Drinking Water. Advisory Committee on Toxicology, National Academy of Sciences, National Research Council, May 1977. (reference 58).

clorethane and dibromochloromethane are included; it is probable that they are more carcinogenic than chloroform. I assume that the NAS report has already allowed for cancers at other than at the primary site.

I.5. Benzo (α) pyrene (BαP)

Polluted air contains many carcinogens. One that has been identified and its carcinogenicity noted is benzo (α) pyrene. It is also frequently monitored. There are other polycyclic organic compounds that are probably carcinogenic, but they have not all been monitored.

If we make the assumption--reasonable for a rough calculation and in any case all we can do--that all burning processes produce the carcinogenic polycyclic hydrocarbons in equal proportions, then a monitoring of benzo (α) pyrene can give us a relative hazard index. This can be made into an absolute hazard index by epidemiological studies of which I here quote two: a study of lung cancer in British gas workers[9] and a comparison of lung cancer in industrial Liverpool and rural North Wales.[10] In each case the increase of lung cancer (among non-smokers) is tentatively attributed to polycyclic hydrocarbons with benzo (α) pyrene as an index. These are compared, for example, in a review[11] and it is stated that it is prudent to assume that breathing air with an average concentration of 10 ng/m^3 is equivalent to smoking one cigarette a day.

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[9] P.J. Lawther, B.T. Commins, R.E. Waller, "A Study of the Concentration of Aromatic Hydrocarbons in Gas Workers' Retort Houses." Br. J. In. Med., 22, 13 (1965).

[10] P. Stocks, "Cancer in N. Wales and Liverpool Region," Supplement to British Empire Cancer Campaign Annual Report, 1951.

[11] Malcolm. C. Pike, et. Al., "Air Pollution," Chap. 14 in Persons at High Risk of Cancer, Ed. J.F. Fraumeni. Academic Press (NY) 1975.

TABLE 2
Age-standardized lung cancer mortality rates (per 100,000 per year)
for men aged 35-74 by amount of cigarettes smoked
in Liverpool and rural North Wales [~~26~~] [reference 10]

Packs/day (approx.)	Mortality Rates	
	Rural area	Liverpool
Nonsmokers	22	50
½	69	168
1	147	248
1½	232	389
2	344	327

TABLE 3

Estimated increase in male lung cancer death rate (per 100,000 per year) per ng/m^3 BP content of air and per cigarette smoked per day

Data source		Increase per ng/m^3 BP in air	Increase per cigarette smoked per day	Estimated U.K. equivalence: ng/m^3 BP =1 cigarette/day	Estimated U.S. equivalence: ng/m^3 BP =1 cigarette/day
British carbonization workers [~~21, 22~~] [ref 9]		0.4	9	23	11
Liverpool and rural North Wales [~~26~~] [ref 10]	Non-smokers	0.4	7	17	9
	Cigarette smokers	1.4	7	5	2.5

This "match" was made for lung cancer; but because of the similarities between cigarette smoking and air pollution, I will assume that the other problems of cigarette smoking--such as other cancers, including bladder cancer, and heart disease, also occur with polycyclic organic matter in the same proportion. The total average risk from cigarette smoking in the U.K. is 0.7×10^{-6}/cigarette[12] or about 2×10^{-4} for 1 cigarette/day, and about half this in the U.S.

Even as late at 1970, many American cities had ambient concentrations out of doors of benzo (α) pyrene of 1.5 ng/m^3, giving a yearly risk of 1.5×10^{-5}. Indoors the concentration is less, leading to an overall risk of half this amount.

Benzo (α) pyrene is also a known animal carcinogen of some potency. Data on Chinese hamsters where benzo (α) pyrene is ingested daily for a lifetime gives a potency such that there is 50% tumor induction for 100 μg ingested per kg body weight per day.[13] This potency agrees with the mutagenic potency of 5×10^{-2} μg/100 salmonella revertants in an Ames test, as shown by Meselson.[14]

Benzo (α) pyrene also gives cancers when injected into rats and mice subcutaneously. It is a constituent of cigarette smoke and may be the most active carcinogenic agent in cigarettes.

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[12] R. Doll and A.B. Hill, Brit. Med. J., 1, 1399 (1964).

[13] E. Chu and R. Malmgren, Cancer Res., 25, 884 (1965).

[14] loc. cit. (reference 34 in main text).

Benzo (α) pyrene and many other polycyclic hydrocarbons are produced in various incomplete combustion processes--open wood and coal burning, broiling of fish, chicken and meat , and automobile exhausts which I discuss in the next section.

I note, however, that the carcinogenic risk of benzo (α) pyrene ingested is less than calculated above for benzo (α) pyrene as an index of polluted air. Thus, about 1 ng/m^3 of benzo (α) pyrene polluted air gives a yearly risk of 10^{-5} and a lifetime risk of 6×10^{-4}. Thus a 60% tumor incidence is reached at 1000 times this concentration or 1 μg/m^3.

Man breathes in 10-20 (average 15) cubic meters of air per day,[15] so a man breathing this polluted air will breathe in 5 μg of benzopyrene per day or 0.2 μg ingested per kg body weight. Assuming this is all absorbed, this can then be compared to the dose for which Chinese hamsters have 50% tumor induction (which I read from the figure presented earlier from Meselson's paper (reference 34). This is 500 times greater than the air pollution figure of 0.2 μg (micrograms) indicating a <u>smaller</u> carcinogenic effect.

Part of this difference is, no doubt, because benzo (α) pyrene is only an <u>indicator</u> of many other carcinogens in smoke from incomplete combustion of carboniferous products. Also, perhaps, the mode of intake through the lung emphasizes lung cancers.

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[15] National Academy of Sciences, Particulate Polycyclics Organic Matter, Washington, DC, 1972, p. 29.

In this case, although at first sight it appears that one can have a direct comparison of human and animal data, the fact that benzo (α) pyrene is merely an indicator for other carcinogens, upsets the comparison and the human effect is larger than a naive use of the animal data would suggest.

I.6. Charcoal Broiling Steaks

It has been noted that many carcinogens are produced in detectable amounts when steaks are charcoal broiled. Char-broiled chicken and broiled fish are also covered with carcinogens. These can come from the charcoal--it is well known that burning coal produces many carcinogens, and the first cases of environmental carcinogenesis noted by Sir Percival Potts 200 years ago came from burning coal--or they can come from the high temperature.

For example, Lijinsky noted over a dozen potential carcinogens[16] from broiling steaks. Of these, benzo (α) pyrene is the best known, and I use only this for this calculation which is therefore <u>a lower limit</u>. Nine micrograms is present in a 1 kg (2 lb) steak or 9 ppb or 2.2 micrograms for a 1/2 lb. steak. Benzo (α) pyrene may be the principal active agent in tobacco smoke and this corresponds to 900 cigarettes. Of course, lung cancer caused by cigarette smoking is caused by inhalation; data shown earlier in Figure 2 show that 50% of that 5 develop tumors when ingested with 0.1 mg/kg body weight. This leads to a carcinogenic potency potency of 5.5 for 1 mg/kg body weight ingested per year and leads to a risk for 1/2 lb. steak per week of 4 x 10^{-7}. The FDA has not yet banned charcoal broiling in restaurants even though it involves the processing the food and adding of carcinogenic substances.

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[16] W. Lijinsky and P. Shubik, <u>Science</u>, <u>145</u>, 53 (1974).

The huge variety of ways benzo (α) pyrene can add itself to the food chain in concentrations of 10 parts per billion is illustrated by the section from the monograph of IARC.[17] In many countries smoked fish is believed to be a cause of stomach cancer.[18]

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[17] The International Association for Research on Cancer Monograph, pp. 94-103, 1973.

[18] Occupational variations in mortality from gastric cancer in relation to dietary differences. J. Sigurjonsson, Brit. J. Cancer, 21, 65 (1967).

I.7. Aflatoxin

Aflatoxin is one of the most potent carcinogens. It appears in nature extensively. It grows on molds of various sorts.

Although it grows naturally it is important to realize that it can be controlled by society. The storage of grains can be careful or careless and the concentration of aflatoxin low or high accordingly. For peanuts the mold grows on the case, and if care is taken to throw out the nuts with cracked cases, the concentration can be further reduced.

A summary of the data on aflatoxins was made by the FDA.[19] At that time, the action level for concentration of aflatoxins in peanut butter was 20 microgram/kg (20 ng/kg $\simeq 2 \times 10^{-8} \simeq$ 20 parts per billion) and FDA proposed to reduce it to 15 ng/kg. Although they do not state it clearly in this document, a suggestion is made that the average concentration in American peanut butter is 3 parts per billion (compared to 200 parts per billion in sections of Thailand!) I will take this for the risk estimate.

The epidemiological data on man[20] suggests a lifetime risk <u>for liver cancer only</u> of 2×10^{-4} to 10^{-3} for 0.1 ng daily intake in a

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[19] 39 Federal Register, 42748, Dec. 6, 1974.

[20] F. Peers and C. Linsell, "Dietary Aflatoxins and Liver Cancer: A Population Based Study in Kenya," <u>Brit. J. Cancer</u>, <u>27</u>, 473 (1973).
R. Shank, J. Gordon, E. Wogan, A. Nondasuta, and B. Subhamani, "Dietary Aflotoxins and Human Liver Cancer III: Field Survey of Rural Thai Families for Ingested Aflatoxins," <u>Fd. Cosmet. Toxicol. 10</u>, 71 (1972b).
S. Van Rensberg, J. Van der Watt, I. Purchase, L. Pereira Coutinko, L. Markham, "Primary Liver Cancer Rate and Aflatoxin Intake in a High Cancer Area," <u>S. Afr. Med. J.</u>, <u>38</u> 2808a (1974).

man (average weight 70 kg).

This agrees with a rough average of 3 animal experiments,[21] for the same relative intake (expressed in mg/kg body weight for a lifetime) and mutagenesis tests[22] as interpreted by Meselson.[23] I note in passing that this is an example where animal and human carcinogenesis and mutagenesis data simultaneously exist.

This then gives a lifetime risk (read from Meselson's graph) or calculated direct from the data of

$$\frac{\log 2}{3 \times 10^{-3}} \quad \text{(Dose in mg/kg body weight/day)}$$

or 3×10^{-4} for 0.1 μg human intake/day.

For 3×10^{-9} concentration of aflatoxin in peanut butter, I find one tablespoonful (16 grams) gives 48×10^{-9} gms/aflatoxin day; 4 tablespoonsful peanut butter a day gives a lifetime liver cancer risk of 6×10^{-4}; and a yearly liver cancer risk of 10^{-5}. To obtain a total risk, I assume other cancers are produced in numbers equal to the liver cancers, and as many heart disease

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[21] W. Butler and J. Barnes, "Carcinogenic Action of Ground Nutmeal Containing Aflatoxin in Rats," Fd. Cosmet. Toxicol., 6, 135 (1968). W. Butler, M. Greenblatt and W. Lijinsky, "Carcinogenesis in Rats By Aflatoxins B1, G1, and B2, Cancer Res., 29, 220 6 (1969). G. Wogan, S. Papliolunga and P. Newbreme, "Carcinogenic Effects of Low Dietary Levels of Aflatoxin B1 in Rats., Fd. Cosmet. Toxicol. 12, 681 (1974).

[22] J. McCann, E. Choi, E. Yamasaki, and B. Ames, "Detection of Carcinogens in the Salmonell/Microsource Test: Assay of 300 Chemicals," National Academy of Sciences: USA, 72, 5135, 1975.

[23] M. Meselson and K. Russell, loc. cit. (reference 34 in main text)

as cancers; this is the case for cigarette smoking and probably for vinyl chloride as noted earlier in my suggestions for risk estimation.

This is lower than earlier estimates of mine. The reductions come from three causes. Firstly, there is a reduction from 15 x 10^{-9} to 3 x 10^{-9} in the estimate of average aflatoxin concentration. But concentrations of 15 x 10^{-9} are allowed by present regulations. I also took the most pessimistic of animal studies. In my first estimate, moreover, I related animal to man at the same intake as a fraction of food intake (rather than as a fraction of body weight). This overstates the risk. I believe the value here is more reasonable.

We can also calculate the danger of aflatoxin in milk. According to recent surveys[24] levels of 0.1 ppb and above were found in 177 out of 302 samples--or roughly half. An average level might then be 0.1 ppb. One pint of milk (= 1/2 liter = 500 gm) contains as much aflatoxin as one tablespoonful (16 grams) of peanut butter with 3 ppbillion.

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[24] Food Chemical News, p. 22, November 7, 1977, and p. 38, Nov. 28, 1977.

I.8. Alcohol

The cases of cirrhosis of the liver are assumed to be entirely due to alcohol consumption, the rate I assume to be proportional to the consumption. This is suggested by the WHO study referred to earlier where data for 14 countries, with average annual per capita intake varying from 4 to 25 litres were compared. In the U.S. the rate in 1974 was 2.1×10^{-4} for men and 1.1×10^{-4} for women[25] (the difference being consistent with the relative consumption of men and women) or an average of 1.6×10^{-4}.

The evidence for carcinogenicity of alcohol is confusing. It is unclear whether alcohol functions as a carcinogen, cocarcinogen, or through an indirect mechanism such as alteration of bacterial flow through the gastro-intestinal tract. Moreover, some or all may be due to impurities in the beer or wine. But for our purposes, these caveats don't matter. People drink beer or wine impurities and all; and the intake is large enough that we are almost certainly above any threshold. But there is, for oral cancer at least, a very strong synergism between smoking and alcohol. There have been correlations between cancer and alcohol intake noted for the mouth and pharynx, larynx, esophagus, liver and possibly rectum.

Rothman[26] estimates the overall risk as follows. In 1968 14,454 cancers occurred in sites where alcohol has been associated, out of

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[25] Statistical Abstract of the U.S.A., Tables 89, 93, 1317.

[26] K.J. Rothman, Ch. 9 in Persons at high risk of cancer. An approach to cancer etiology and control. Ed. J.F. Fraumeni. Academic Press 1977.

173, 665 total cancers in the U.S.A. This gives a risk of $7\text{x}10^{-5}$/yr. These are probably concentrated in the 20% of heavy drinkers (who are usually also smokers) to give a risk of $2\text{x}10^{-4}$/yr.

The average beer consumption in the U.S. is 2/3 pint/day[27] with approximately double the amount of alcohol consumed in wine and spirits. A light drinker (1 pint beer per day only) still has a risk of cirrhosis of $7\text{x}10^{-5}$/yr.

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[27] Statistical Abstract of the U.S. Table 1317.

I.9. Egg Yolk

Mice have been fed an extract from the yolk and the whites of hens' eggs and cancer has been induced.[28] The mice were not only fed for a lifetime, but to the offspring also for four generations.

The mice were fed 175 mg daily of extract. Assuming 25 grams per mouse, this is 7 grams/kg body weight. Sixty percent of the mice got tumors, corresponding to potency x dose = 1 for this dose since [1 -exp (-1)] ≈ 0.6 (60%).

Man weighs 70 kg so if fed 500 grams per day he should also develop tumors at this rate. One egg weights 80 grams, so that according to this calculation anyone eating one egg per day has a 16% risk of cancer. I assume this is a lifetime risk, and discount the effect of feeding over several generations. The yearly risk becomes 3×10^{-3} for one egg/day which is a common dose.

This is a test at one laboratory only; so it would not warrant regulatory action and I do not include it as a risk in my tables. Nonetheless, risk is so much higher than the other risks in the table that further work seems necessary.

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[28] J. Szepsenwol, Proc. Soc. Exp. Biol. and Med., <u>112</u>, 1073 (1963); <u>116</u>, 1136 (1964).

I.10. Air Pollution--Sulphates, etc.

The National Air Quality Standards were set at a time when a threshold concept was dominant. The threshold concept suggests that if the concentration of sulphur dioxide, for example, in the air can be brought below a threshold, then there is no adverse health effect.

The threshold was chosen to be a level where no health effects had been observed, with a suitable safety margin. This was as a result of a very careful survey of data on a small number of people.[29]

The effects of sulphur oxides on people are mostly irritation of the bronchial tract. It transpires that careful measurements on animals by Dr. Amdur[30] and co-workers show that the resistance to bronchial flow in guinea pigs is in direct proportion to the sulphate concentration but the sulphates (sulphuric acide, zinc ammonium sulphate, which are prevalent in power plant plumes) are more important than others which come from natural causes (sodium sulphate or sulphur dioxide).

For a given mass of pollutants, the resistance is worse for small particles--just the size that escape the electrostatic precipators of a power plant. The sodium sulphate particles that form naturally in the environment come in larger particulates which get filtered in the nasal passages.

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[29] "Air Quality Control Criteria for Sulphur Oxides," AP-50, Environmental Protection Agency Report, Washington, D.C.

[30] M.O. Amdur, "Animal Studies," for Conference on Health Effects of Air Pollution, National Academy of Science, Oct. 3-5, 1973; M.O. Amdur, "The Long Road from Donora," Memorial Lecture, 1974; M.O. Amdur, Arch. Environ. Health, 23, 459 (1971); M.O. Amdur, Journal of the Air Pollution Control Association, 14, 638, (1968).

There are also some large scale epidemiological surveys. A study shows that incidence of bronchitis in 7 Japanese cities[31] is proportional to the sulphate level and Lave and Seskin[32] show the same effect for the mortality rate in the U.S. In Norway, the death rate in 156 winter weeks shows a linear relationship with the SO_2 concentration.[33] The numerical calculation has been confirmed by a recalculation of the same data.[34] Finally, the CHESS studies from the EPA[35] show health effect at sulphate levels as low as 10 $\mu g/m^3$, whereas sulphate levels at eastern cities are 20 $\mu g/m^3$.

These data are consistent with a linear relationship between mortality and sulphate concentrations with no threshold above the ambient levels and for public policy purposes this linear relationship should probably be used.

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[31] Y. Nishiwaki, et al., "Atmospheric Contamination of Industrial Areas including Fossil Fuel Stations and the Method of Evaluating Possible Effects on Inhabitants." Report to the Conference on Environmental Effects of Nuclear Power Stations IAE-SN-145/16, International Atomic Energy Agency, Vienna.

[32] L. Lave and E. Seskin, "Air Pollution and Human Health," Science, 169, 723 (1970).

[33] W. Lindbergh, "General Air Pollution in Norway" Report from Smoke Damage Council, Oslo, 1968. Data plotted in ref. 30, main text.

[34] Report from Biomedical and Environmental Assessment Group, BNL 20582, 30 July 1974, edited by L.D. Hamilton, Brookhaven National Laboratory, Upton, NY.

[35] J. Finklea, et al., "Health Effect of Sulphur Oxides", U.S. Environmental Protection Agency, referred to in Air Quality and Stationary Source Emission Control, prepared for the Committee on Public Works, U.S. Senate, Serial 94-4, March 1975.

The differences between the threshold approach and the linear approach is considerable. Most cities in the U.S. are now in compliance with the sulphate and particulate levels of the Clean Air Act and if the levels were correctly set below the threshold there would be no mortality. With the recent data and the linear relationship, we calculate that about 20,000 persons per year east of the Mississippi have their lives shortened by up to 20 years by air pollution.[36]

Although these data suggest that sulphates are the cause of this mortality, this is not proven. Those cities which have high sulphate levels usually have high nitrate levels and particulate levels as well and the distinction is not clear. Moreover, the gases and particulates contain large quantities of known carcinogens and trace quantities of mercury and other heavy elements.[37]

The procedures for mitigation of the air pollution effects differ depending upon the existence or not of a threshold. If there is a threshold, supplementary control systems can be used to reduce sulphur emissions during unfavorable weather conditions so that the concentrations stay below the threshold.

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[36] See press release from BNL, July 1977; also Wilson and Jones, Energy, Ecology and the Environment, Academic Press, New York, 1974. Ch. VIII

[37] Wilson and Jones, Ibid ., Chap. VIII.

On the other hand, associated with any theory of the linear relationship is that the health effect is proportional to a long term average. Then supplementary control systems are of little use. This has led EPA to insist that sulphur be removed by stackgas scrubbers. If, however, the health effect is due to nitrates or particulates, this might be a useless waste of money. A far better mitigation procedure would be to insist that power plants be located hundreds of miles downwind of major population centers--such as on the northeastern seaboard of Maine--the health effects are reduced. In a report for ERDA,[38] Chang and Wilson show that mortality reduction factors of 10 or more can be obtained independently of which of the effluents actually cause the health effect.

I note that this is not a cancer risk. But there is probably a cancer risk due to polycyclic aromatic hydrocarbons of which benzo (α) pyrene is the usual indicator. These seem to concentrate in cities, and do not seem to have the long range effects of sulphur and nitrogen oxides. The cancer effect, for urban populations only, is calculated in the section on benzo (α) pyrene.

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[38] B. Chang and R. Wilson, "Mitigation of the Effects of Sulphur Pollution," Energy and Environmental Policy Center Report, Harvard University, Cambridge, MA. 02138, July 5, 1976.

I.11. Accident Risks

The accident risks are calculated a little differently in each case. The total number of deaths are divided by the number at risk. The sources of these numbers is listed in the tables.

The calculation sounds simple, but they must be made with circumspection. For example, I noted 46,000 deaths due to motor vehicle accidents, and it might be thought that the risk is a risk to the motor vehicle driver. But 8,600 are in collisions with pedestrians. I assume here (though the source quoted does not say) that most of these deaths are the death of the pedestrian usually due to no action on the pedestrian's part. Over 1/4 of the pedestrians killed are children, so that it may be reasonably assumed that alcohol consumption of the pedestrian is not a large factor.

In many cases, sources and calculations of other authors give different numbers. I have worked at these, and chosen the most plausible. In any case, the risk is good to better than a factor of 2 which is as good as the cancer risks are known.

Again in calculating the risk to truckers, and tractor drivers, I use data on accidents (for the numerator) and total number of trucks or tractors in use. I assume there is one driver per truck or tractor. Likewise for fishing accident risks, I use as the denominator in the risk equation the total number of fishing licenses, although in many of these cases the fishermen are firmly on shore and not subject to appreciable risk of drowning.

We are used to the ordinary risk of air travel which is the risk of accident. At the present time, air travel is fairly safe: one death for 1000 million miles of travel on a scheduled carrier.[38] The risk is, of couse, concentrated at take off and landing. Nonetheless, I use this to get a figure for the risk of accident for one 3000 miles (cross-country) flight; it is 3000/(1000 million) or 3×10^{-6}. One such flight per year gives a risk of 3×10^{-6} per year. A pilot, flying the FAA maximum of 50 hours/month has an accident risk of 3×10^{-4}.

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[39] Bureau of Aviation, National Transportation Safety Board; see also: Accident Facts, 1976 Edition.

REV. Dec. 1, 1977

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EDUCATION

St. Paul's School, London, England
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Open Mathematical Scholar	1943
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M.A., Ph.D.	1950

POSTIONS

Research Lecturer, Oxford	1949-50
Research Associate, University of Rochester	1950-51
Research Associate, Stanford University	1951-52
Research Officer, Clarendon Laboratory, Oxford	1952-55
Assistant Professor, Harvard University	1955-57
Associate Professor, Harvard University	1957-61
Professor, Harvard University	1961-present
Acting Director, Energy and Environmental Policy Center, Harvard	1976-present
Associate, Adams House, Harvard University	1971-present

SUMMER AND VISITING POSITIONS

Stanford University	1958
John Simon Guggenheim Fellow, University of Paris-Sud (Orsay)	1961
Fulbright Fellow, Laboratori Naxionali di Frascati, Rome	1969
Lecturer on Energy and the Environment, Summer Institute Lawrence Radiation Laboratories, Berkeley, CA	1973
Lecturer, Second Energy Symposium, Boulder, CO	1974
Lecturer, Summer School on Aspects of Energy Conversion, Oxford, England	1975

COMMITTEE, CONSULTANT, OTHER POSITIONS

Assistant Editor, Annals of Physics	1956-present
National Science Foundation, Physics Advisory Panel	1967-70
Trustee, Universities Research Association	1968-73
Consultant to Attorney General's Office, State of Maine	1971-72
Transportation Advisory Committee, City of Newton	1973
Consultant to Energy Research and Development Administration	1974-present
Consultant to Nuclear Regulatory Commission	1974-present
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Consultant to General Accounting Office	1977-present
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SOCIETIES

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Member--Newton Conservators (Board of Directors 1972-76)

Attachment 2

"A Catalogue of Risks," B. L. Cohen, I.S. Lee, Health Physics, Vol. 36, June 1979, p. 701-722.*

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* AMC does not necessarily endorse every statement made in this document. We have referenced certain materials from this document in our written and oral comments and it is attached hereto for the reader's convenience.

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A CATALOG OF RISKS

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Abstract—Information on risks is collected from various sources and converted into loss of life expectancy throughout life and in various age ranges. Risks included are radiation, accidents of various types, various diseases, overweight, tobacco use, alcohol and drugs, coffee, saccharin, and The Pill, occupational risks, socioeconomic factors, marital status, geography, serving in U.S. armed forces in Vietnam, catastrophic events, energy production, and technology in general. Information is also included on methods for reducing risks, risks in individual actions, "very-hazardous" activities, and priorities and perspective. Risks of natural and occupational radiation and exposure to radioactivity from the nuclear industry are compared with risks of similar or competing activities.

INTRODUCTION

THE PUBLIC is constantly harrangued about all sorts of risks, and its perception of risks plays an important role in governmental decision making. The risks of radiation have especially been emphasized in the popular press. This creates a very serious problem since the public does not understand risk. It gets highly excited about radiation risks which are almost never fatal, whereas it largely ignores other risks which claim thousands of lives every year.

One possible reason for this situation is that risks are not generally expressed in understandable terms. They are usually given as annual mortality rates, which are nearly always smaller than 10^{-3}, whereas there is good evidence that the public recognizes little difference between an annual risk of 10^{-3}, 10^{-6}, and 10^{-9}. An expression of risk more understandable to the public would be in terms of days of life expectancy lost; one purpose of this paper is to translate the data into those terms. A complication in that process is that the value of lost life expectancy is generally viewed as varying considerably with the age at which the time is lost—a year lost in the prime of life by a parent of small children is generally more regretable than a year lost in advanced old age. We therefore give results in terms of life expectancy lost in various age ranges.

DEFINITIONS AND CALCULATIONAL PROCEDURES

The basic information in calculating life expectancy is a set of $R(I)$, the mortality rate (or probability of death) during year I defined as starting on the Ith birthday. Given $R(I)$, one may calculate $P(M, N)$, the probability of death at age N for a person who is alive on his Mth birthday, as

$$P(M,N) = [1-R(M)] \times [1-R(M+1)] \cdots [1-R(N-1)]R(N). \quad (1)$$

It may be noted that $P(K,K) = R(K)$, and

$$\sum_{N=M}^{\infty} P(M,N) = 1. \quad (2)$$

The life expectancy between ages M and Q (actually between the Mth and Qth birthdays), $E(M, Q)$, is then

$$E(M,Q) = \sum_{N=M}^{Q-1} P(M,N)\cdot(N-M+0.5) + \sum_{N=Q}^{\infty} P(M,N)(Q-M). \quad (3)$$

For $Q = \infty$, (3) was shown to be mathematically equivalent to the standard procedure (PH75) for calculating life expectancy.

It should be noted from (3) that for an intermediate age S

$$E(M, Q) \neq E(M, S) + E(S, Q) \qquad (4)$$

since the second term on the right side of (4) presumes that all members of the group are alive at age S whereas this is not true for the term on the left side of (4).

$R(I)$, based on 1974 statistics (PH75), are used with (1) and (3) to calculate the values of $E(M, Q)$ shown in Table 1. Results are shown there for the total U.S. population, for all males, all females, all whites, all non-whites, white males, white females, non-white males, and non-white females. All of these are necessary for analysis of some of the risks we will be discussing since $R(I)$ are often given separately by sex and/or race.

It would clearly be very cumbersome to present data for all values of M and Q, so some selection is necessary. Additional data beyond that given in the Tables are available from the first author.

In most situations, data are available as the mortality rate due to a particular risk, x, as a function of age, $r_x(I)$. If the risk x were eliminated, $R(I)$ would be reduced to $R_x(I)$ given by

$$R_x(I) = R(I) - r_x(I) \qquad (4)$$

and the $R_x(I)$ may be used with (1) and (3) to calculate revised values of $E(M, Q)$, which we designate $E_x(M, Q)$. The loss of life expectancy, $\Delta E(M, Q)$, due to the risk x is then

$$\Delta E(M, Q) = E_x(M, Q) - E(M, Q). \qquad (5)$$

Table 1. E(M, Q) *in years for various groups used as comparisons*

Group	Age range 0–55	55–70	70–85	85–∞	0–∞
Total population	52.6	13.3	10.5	5.4	71.3
All males	52.0	12.7	9.3	4.4	67.6
All females	53.4	13.9	11.3	5.6	75.3
White males	52.3	12.7	9.3	4.3	68.3
Non-white males	49.7	12.0	9.1	5.5	61.7
White females	53.5	14.3	11.4	5.4	75.9
Non-white females	52.0	13.0	10.5	6.7	69.7

Table 2. ΔE(M, Q), *loss of life expectancy in days for some simple age dependences of r and p for various population groups*

Group, r or p		Age range 0–55	55–70	70–85	85–∞	0–∞
Tot. pop.,	$r = 1 \times 10^{-5}$	5.25	0.372	0.259	0.096	9.98
	$r = 100 \times 10^{-5}$	534	37.4	26.0	9.60	1024
	$p = 1.001$	1.00	0.614	1.37	1.53	5.04
	$p = 1.1$	99.9	60.9	133	142	482
$r = 10 \times 10^{-5}$,	white male	52	3.5	2.2	0.66	92
	white female	54	4.0	2.9	0.95	111
	non-W M	48	3.3	2.2	1.0	78
	non-W F	51	3.6	2.6	1.4	97
$p = 1.01$,	white male	11	7.6	15	13	49
	white female	6.7	4.1	12	15	44
	non-W M	20	10	16	16	62
	non-W F	12	6.5	14	17	56
$r = 10 \times 10^{-5}$	white M	23	3.1	0	0	50
age 18–64	white F	24	3.5	0	0	61
	non-W M	21	2.9	0	0	41
	non-W F	23	3.2	0	0	53

Some simple examples of interest are shown in Table 2; these include calculations of $\Delta E(M, Q)$ for $r_x(I) = 1 \times 10^{-5}$ and 1×10^{-3} for all I. We see that $\Delta E(M, Q)$ depends linearly on the $r_x(I)$ to rather good accuracy over a very wide range.

In some situations, data are available as mortality ratios, $p(I)$, defined as

$$p(I) = R_y(I)/R(I) \qquad (6)$$

where R_y are the mortality ratios for some group of interest, y. Since the $R(I)$ are known, the $p(I)$ are readily converted to $R_y(I)$, allowing the calculation to proceed as before. Examples for $p(I) = 1.001$ and 1.10 are given in Table 2. Here we see a rather accurate linear dependence on $[p(I) - 1]$ although in this case the added risks are different for each I. These linearities imply that if two different risks have the same age dependence, the $\Delta E(M, Q)$ for one can be derived from those for the other by simply multiplying by the ratio of the $r_x(I)$ or $[p(I) - 1]$.

We now proceed to consider various categories of risk and calculate $\Delta E(M, Q)$ for them. In some situations where available data are limited, we will consider only the total change in life expectancy, $\Delta E(0, \infty)$ which we abbreviate as ΔE.

RADIATION

The BEIR Report (NA72) develops and uses an absolute risk model and a relative risk model for estimating effects of low-level radiation, and in each case considers "plateau lengths", i.e. duration of increased susceptibility to cancer due to radiation exposure, of 30 years and full lifetime. In the absolute risk model there is little difference between the results for the two plateau lengths, so we adopt an average between the two. In the relative risk model, there is a substantial difference between the two plateau lengths when exposure to children is involved; we therefore give results for both cases.

The loss of life expectancies due to natural radiation, taken to be 100 mrem/yr whole body exposure, are listed in Table 3 for the three cases discussed above. The mortality rates $r(I)$ are taken from the BEIR Report pp. 172 and 173.

The data for the absolute risk model given in the BEIR Report, p. 173, lead to a total of about 1850 fatalities per year whereas the BEIR Summary gives a best estimate of 3500. To be consistent with the latter, one should multiply values by $3500/1850 = 1.9$. This procedure gives $\Delta E = 9$ days The same treatment for the relative risk model with the 30 yr plateau, which results in 3170 fatalities/yr according to the BEIR Report, p. 172, means multiplying 8.1 times 3500/3170 which gives $\Delta E = 9$ days, and for the relative risk model with infinite plateau this gives $\Delta E = 23 \times 3500/8930 = 9.0$. The BEIR estimate is therefore $\Delta E \simeq 9$ days.

In a previous paper (Co79) it was shown that the basis for the relative risk model is highly questionable, and the form in which it is used in the BEIR Report is almost certainly erroneous. On the other hand it is shown that an age dependent absolute risk model is quite reasonable and that the form of the age dependence, so long as it is even crudely consistent with the data, is essentially irrelevant. The results for the absolute risk model are therefore the more credible. Perhaps the best procedure is therefore to use the number from the BEIR absolute risk model in Table 3 and multiply by $19/5 = 1.8$. If the natural radiation level is different from 100 mrem/yr, all values in Table 3 should be scaled proportionally, and the same is true, of course, if there are additional sources of exposure received regularly (averaged over a few years) such as that due to fallout.

The average dose to those occupationally exposed to radiation is about 500 mrem/yr, and this additional exposure may persist from ages 18 to 65. The loss of life expectancies from this exposure, calculated with the BEIR absolute risk model, are also listed in Table 3. For some occupationally exposed persons, the annual exposure may be up to ten times higher, 5000 mrem/yr; in such a case, the values in Table 3 should be scaled proportionately. For consistency with the BEIR Report Summary, an additional factor of 1.8 should probably be applied, raising ΔE from 500 mrem/yr to $18 \times 1.8 = 36$ days of lost life expectancy.

Routine releases of radioactivity from the nuclear industry would be expected to give the average American an additional exposure of about 0.2 mrem/yr (Co76; AP78; Po76, NR76) if all U.S. electric power were nuclear. This is 0.2% of natural radiation exposure and therefore gives $\Delta E = 0.002 \times 11 = 0.022$ days $\simeq$ 30 min.

Table 3. ΔE(M, Q), loss of life expectancy due to natural radiation (100 mrem/yr) at all ages and occupational radiation (500 mrem/yr) from age 18–64

Basis	Age range				
	0–55	55–70	70–85	85–∞	0–∞
BEIR absolute	1.4	0.63	0.52	0.23	5.0
BEIR relative (30 yr)	1.7	0.98	1.3	0.82	8.1
BEIR relative (lifetime)	2.0	4.3	7.1	4.5	23
Occupational	2.2	4.3	3.8	1.3	18

ACCIDENTS

Mortality rates as a function of age are given in the National Safety Council annual booklet "Accident Facts"; to be consistent with our data base, 1974 statistics are used (NS75). The results are listed in Table 4 for

Table 4. ΔE(M, Q), loss of life expectancy in days for average American due to various types of accidents

Type of accident	Age range				
	0–55	55–70	70–85	85–∞	0–∞
All accidents	202	19	31	19	435
Motor vehicle	106	7.1	6.7	3.0	207
Pedestrian	18	1.6	2.6	1.4	37
Pedalcycle	3.2	0.08	0.05	0.02	5.1
Accid. in home	42	4.1	13	9.3	95
Falls	7.7	2.7	14	11	39
Drowning	23	0.9	0.6	0.2	41
Fire, -burns	12	1.6	2.3	1.2	27
Poison (sol., liq.)	7.9	0.7	0.5	0.2	17
Suffocation	6.1	0.7	0.8	0.5	13
Firearms	6.4	0.3	0.2	0.07	11
Poison (gas)	3.6	0.3	0.2	0.09	7.5

all accidents, accidents in the home, and for those due to motor vehicles (total, and pedestrian deaths only), pedalcycles, falls, drowning, fire and burns, poisoning by solids and liquids, suffocation, firearms, and poisoning by gas. An especially evident effect of different age dependences may be seen by comparing numbers for motor vehicles and falls; for ages 0 to 55, the ratio of loss of life expectancies for these is 14, whereas for ages 85 to ∞ it is 0.28, a variation by a factor of 50.

There are substantial differences in accident risks between males and females. Mortality rates from major causes of accidental death in 1968 (Me71) are used to obtain the results in Table 5. We see that, in general, males are more susceptible to accidents—7% of all males vs 4% of all females die in accidents—and that the differences are especially large for automobile accidents (including pedestrian fatalities), drowning, and firearms (too small to be listed for females). Total loss of life expectancy due to accidents, ΔE, is 669 days (1.8 yr) for males and 363 days (1.0 yr) for females. Accident mortality has decreased by 22% over the past decade, which means that improved safety has added about 110 days to the life expectancy of the average American over this period.

DISEASE

Mortality rates vs age for various diseases from "Statistical Abstract of the United States" (Ce75) are used to calculate the $\Delta E(M, Q)$ in Table 6. The values for heart disease and cancer are given in years (in the first four lines) whereas for other diseases they are given in days.

Table 5. ΔE(M, Q), loss of life expectancy in days due to accidents for all U.S. males and all U.S. females

Accident type, sex	Age range				
	0–55	55–70	70–85	85–∞	0–∞
All accidents—M	333	38	40	12	669
F	108	18	36	13	297
Motor vehicle—M	195	15	13	4.1	363
F	67	7.1	7.2	2.6	150
Pedestrian—M	24	3.6	4.3	1.3	49
F	11	1.4	2.2	0.79	24
Falls—M	12	7.4	15	4.6	49
F	3.4	5.4	21	7.6	52
Fire, burns—M	14	3.0	3.2	0.98	31
F	10	1.8	2.7	0.96	26
Drowning—M	31	1.0	0.66	0.21	49
F	6.2	0.21	0.23	0.08	11
Industrial—M	21	3.2	1.5	0.45	45
Firearms—M	11	0.64	0.29	0.09	19
Choking—F	2.8	0.70	0.88	0.32	8.0
Poison—F	3.9	0.53	0.29	0.10	9.7

Table 6. ΔE(M, Q), loss of life expectancy in days (years in first four lines) due to various diseases for all U.S. males and females

Disease-sex	Age range				
	0–55	55–70	70–85	85–∞	0–∞
Heart disease—M	0.50	0.93	2.3	0.67	6.3
F	0.19	0.50	1.9	0.69	5.4
Cancer—M	0.34	0.43	0.82	0.25	2.6
F	0.32	0.34	0.58	0.21	2.8
Stroke—M	28	59	196	60	389
F	27	61	246	88	627
Pneumonia Influenza —M	21	20	60	18	141
—F	14	13	49	18	142
Homicide—M	71	5.4	1.9	0.6	136
F	19	1.4	0.86	0.31	43
Suicide—M	55	10	8.4	2.6	131
F	21	4.5	2.2	0.80	62
Diabetes—M	9.3	11	26	7.9	70
F	8.7	14	39	14	120
Cirhosis of liver —M	31	22	13	4.1	130
—F	17	11	6.4	2.3	85

It is apparent that heart disease is largely a male problem up to age 55, but at older ages it affects both sexes equally. Homicide and suicide are largely male problems at all ages, whereas stroke and diabetes are more prevalent killers in females.

OVERWEIGHT

Data on mortality ratios for overweight people are available from the "Build and Blood Pressure Study" by the Society of Actuaries in 1959 (Me60) which covered experience on 5 million people insured by 26 large insurance companies between 1935–53. Since the overwhelming number of those insured were white, the standard groups used are white males and white females. Results are given in Table 7 for each sex and for weights 10, 20, and 30% above average. It is perhaps somewhat surprising that the increase with percent overweight is less than linear—one might expect more like a quadratic dependence (Pa58). However, the average weight is about 10–15% above the optimum

Table 7. ΔE(M, Q), loss of life expectancy in years as a function of percentage overweight for white males and females

Sex	% overwt.	Age range				
		0–55	55–70	70–85	85–∞	0–∞
Male	10	0.21	0.33	0.63	0.51	1.6
Male	20	0.43	0.53	0.99	0.78	2.7
Male	30	0.73	0.84	1.5	1.1	4.1
Female	10	0.07	0.12	0.35	0.41	1.0
Female	20	0.16	0.28	0.77	0.85	2.3
Female	30	0.23	0.40	1.0	1.1	3.1

(defined as the weight for maximum life expectancy—Me77a) so 10 and 30% above average are probably about 23 and 46% respectively above the optimum. This makes the ratio of about a factor of 3 between their effects seem not unreasonable.

An average male weighs 160 lb, so a 10% change is 16 lb; this causes $\Delta E \simeq 1.3$ yr = 16 months, or about 1 month/lb. An average female weighs 120 lb, so a 10% change is 12 lb, and it causes $\Delta E = 1.0$ yr = 12 months, or again, about 1 month/lb.

TOBACCO

The principal studies of effects of smoking on mortality rates are those by Dorn on 294,000 holders of veteran's life insurance policies (Ka66) and the American Cancer Society study directed by Hammond of over a million men and women (Ha66). Summaries of these are given in PH67 as the ratio of mortality rates for smokers and non-smokers, (S/N), vs age. Since a large fraction of the population does smoke, not smoking represents an appreciable increase of life expectancy over the average. About 50% of all men and 25% of all women are smokers, so we assume that the mortality ratio relative to that of the whole population for males is $(S/N)^{1/2}$ and $(S/N)^{-1/2}$ for smokers and non-smokers respectively, and for females we take these to be $(S/N)^{3/4}$ and $(S/N)^{-1/4}$; note that these are set to give the proper ratio of mortality rates for smokers and non-smokers, namely S/N.

The results are listed in the left columns of Table 8. The data for males in the two studies are quite consistent and are therefore averaged; only the Hammond study gives results for females. Negative values for non-smokers in Table 8 indicate a negative loss (i.e. a gain) in life expectancy. The large differences between risks for males and females is partly explainable by the fact that women smoke fewer cigarettes per day and do not inhale as frequently or as deeply as males.

Table 8. ΔE(M, Q), loss of life expectancy in years for smokers relative to non-smokers

Group	Age range				
	20–55	55–70	70–85	85–∞	20–∞
Av. male	0.68	1.20	1.52	0.95	5.9
Av. female	0.08	0.22	0.23		1.17
Male—20/day—then stopped 10 + yr	0.17	0.56	0.95		2.3
Male—no inhalation	0.62	1.1	1.0		4.6
Male—deep inhalation	1.2	2.4	2.7		8.6

There is a great deal more detail available on smoking risks, including such dependencies. Table 9 gives the results for some of these from the Hammond study. In many cases, the statistics were too poor to derive an age dependence, so the following procedure was used:

For heavy male cigarette smokers there was a very characteristic mortality ratio age dependence, peaked at age 50, about 80% of the peak value at ages 40 and 65, and 65% of the peak value at age 80. This age dependence was fit to the data where such fits were reasonable. They were not reasonable for women, for pipe and cigar smokers, and for those who had stopped smoking for more than 5 yr. For these cases, the mortality ratio age dependence was essentially constant for 45 to 75, and somewhat less at younger and older ages; the age distribution for women was fitted to all of these cases in Table 9.

Table 9 lists total loss of life expectancy beyond age 20 for each category of smoker. Losses of life expectancy between various

Table 9. Years of life expectancy lost due to various smoking patterns

Type of smoking	Men	Women
Cigarettes—average	6.2	2.2
1–9/day	4.5	0.2
10–19/day	6.2	1.7
20–39/day	6.8	3.5
over 40/day	8.6	
inhalation—none	4.5	0.6
slight	6.4	1.9
moderate	7.2	2.5
deep	8.6	4.6
began after 30	2.0	1.1
25–29	4.5	1.9
20–24	5.7	2.7
15–19	7.7	2.7
before 15	8.6	
had smoked > 20/day		
still smoking	7.6	
stopped 1–4 yr	6.9	
stopped 5–9 yr	3.9	
stopped 10 + yr	2.3	
had smoked 1–19/day		
still smoking	5.9	
stopped 1–4 yr	3.8	
stopped 5–9 yr	3.8	
stopped 10 + yr	0.3	
Cigars only—average	0.9	
1–4/day	0.1	
5 + /day	1.2	
no inhalation	0	
inhalation	3.2	
Pipe only—average	0.6	
no inhalation	0	
inhalation	1.4	

pairs of ages are given for four cases, one female and three male, in Table 8. Values for other cases listed in Table 9 may be linearly interpolated from these, being careful not to confuse between males and females.

It may be noted that there is a puzzling discrepancy between Tables 8 and 9 for average female data; in the former, the difference in life expectancy between smoking and non-smoking females is 1.17 yr, whereas in the latter it is 2.2 yr, nearly a factor of two discrepancy. The latter number and all numbers in Table 9 are based on mortality ratios given in the original report on the Hammond Study (Ha66) whereas the former is based on mortality ratios attributed to that study in a later Public Health Service Review (PH67) using an evaluation procedure that is not explained. The originating groups for both publications were consulted, and neither was willing to concede an error. We therefore present the results from both. For males, there is little difference between the mortality ratios given in the two references.

In view of the large losses of life expectancy listed in Tables 8 and 9, it is interesting to consider what risks for various causes of death are brought about by smoking. Table 10 shows the mortality rates between ages 35–84 for various categories of smokers relative to non-smokers (Ka66) for a selection of fatal diseases. This may be used in conjunction with Tables 6 and/or 8 to estimate the loss of life expectancy due to various diseases as a result of smoking.

ALCOHOL AND DRUGS

Risks to individuals from use of alcohol and drugs are not easy to treat generally or to quantify, but it may contribute perspective to develop estimates of the average loss of life expectancy due to their use in our Society. We use a treatment from NS73.

There are three causes of death on the international list that are directly due to alcohol: alcoholic psychosis—ICDA No. 291—600 deaths/yr; alcoholism—ICDA No. 303—3000 deaths/yr; and cirhosis of liver—alcoholic—ICDA No. 571.0—9500 deaths/yr. About 50% of all motor vehicle deaths are due to alcohol—23,000/yr. About 20% of other accidents, suicides, and homicides are due to alcohol, contributing 12,000, 4300 and 2700 fatalities per year respectively. About 10% of cancers of the esophagus and oral cavity may be blamed on alcohol, contributing another 600 and 700 deaths/yr respectively. This adds up to a total of about 56,000 deaths/yr that may be blamed on alcohol. On an average each of these deaths eliminates

Table 10. Mortality rates for males (relative to non-smokers) in age range 35–84 due to selected causes (Ka66)

	Total deaths	Cigarette—(av./day)				Cigar	Pipe	Ex-cigarette
		Total	1–9	21–39	>40			
All causes	26,166	1.71	1.31	2.0	2.3	1.10	1.07	1.29
Cancer—all types	5383	2.1	1.3	2.7	3.24	1.22	1.25	1.49
buccal cavity	87	3.7	2.1	5.9	9.3	4.11	3.1	1.61
pharynx	58	9.6	4.6	14.4	21.7	0	2.0	1.63
esophagus	104	5.9	2.5	11.9	8.4	5.31	2.0	1.66
stomach	342	1.48	1.69	1.57	1.75	1.20	1.40	1.03
pancreas	344	1.83	1.37	2.2	2.7	1.52	0.74	1.32
lung	1256	10.8	4.8	16.9	23.6	1.59	1.84	4.7
prostate	440	1.71	1.69	1.52	2.4	1.50	1.53	1.63
kidney	141	1.54	0.72	1.96	2.6	0.77	1.32	1.65
leukemia	269	1.49	1.18	1.62	1.40	1.00	1.58	1.55
Bronchitis and emphysema	379	8.6	4.1	11.1	15.0	0.79	2.4	7.6
Influenza and pneumonia	136	1.59	1.36	2.1	0.91	0.71	0.96	0.93
Cardiovascular—all	16,392	1.62	1.29	1.83	1.99	1.05	1.06	1.21
cerebrovascular lesions	2008	1.40	1.26	1.54	1.88	1.08	1.06	1.07
coronary heart disease	10,890	1.61	1.26	1.82	1.97	1.04	1.08	1.21
arterio-sclerosis	692	1.72	1.18	1.85	2.71	0.97	0.99	1.16
Stomach ulcer	90	4.1	2.7	4.1	9.2	2.9	2.8	3.4
Cirhosis of liver	319	2.8	2.3	3.0	5.8	2.9	0.60	1.02
Violence	1042	1.13	0.77	1.28	1.8	0.91	0.91	0.95
Ill defined—unknown	723	1.62	0.93	2.1	3.6	1.13	0.80	1.30

about 20 years of life expectancy, so this loss averaged over the U.S. population is

$$\frac{56{,}000 \times 20 \text{ man-yr lost}}{2.2 \times 10^8 \text{ man-yr lived}} = 0.005 \text{ lifetime}$$

$$= 0.35 \text{ yr.}$$

Improper use of drugs in medical treatment is estimated to cause 75,000 deaths/yr. No estimates have been given of average lost life expectancy per case, but if we guess that this is about 10 yr, the average American loses about 0.25 yr of life expectancy from this cause.

About 2000 deaths/yr are directly due to illicit drugs. In addition, about 40% of suicides by poisoning with analgesic or soporific drugs, 10% of homicides, 2% of motor vehicle deaths, and 1% of other accident deaths are probably due to illicit drugs, bringing the total number of fatalities to about 6000/yr. The average victim loses perhaps 25 yr of life expectancy, which, spread over the total U.S. population, corresponds to an average of 0.05 yr (18 days) reduction in life span for the average American.

COFFEE, SACCHARIN, AND THE PILL

It is estimated (NS73) that 24% of male and 49% of female deaths from bladder cancer are due to coffee drinking. This accounts for 1450 male and 1350 female deaths per year. If it is assumed that there are 180 million coffee drinkers in the U.S., and that each case represents an average of 15 years lost life expectancy, this represents

$$\frac{(1450 + 1350) \times 15 \text{ yr lost}}{180 \times 10^6 \text{ yr lived}} = 2.3 \times 10^{-4} \text{ lifetime lost}$$

$$= 6 \text{ days.}$$

In attributing six days of lost life expectancy to coffee drinking, we ignore all effects other than bladder cancer, such as the known mutagenic properties of caffeine, and effects on the nervous system, weight control, etc.

According to the U.S. Food and Drug Administration (FD77) if everyone in the U.S. were to drink one diet soft drink each day throughout life, there would be an additional 1200 bladder cancers per year. A calculation similar to that above indicates that drinking one diet soft drink per day reduces life expectancy by 2 days. It is interesting to point out that ingesting an extra 100 calories per day, as in drinking a regular soft drink, would increase one's body weight by about 7 lb (Co78) and thereby reduce life expectancy by 7 months or 210 days.

It is estimated that 10% of female deaths from phlebitis and thrombophlebitis are due to oral contraceptives (FD77), which amounts to 150 fatalities per year. If there are 30 million users in the U.S. (75% of all females aged 20–55), and each fatality represents 40 yr of lost life expectancy, an average user of "the pill" gives up 5 days of life expectancy by its use.

OCCUPATIONAL RISKS

Data on mortality rates from work accidents are available annually (NS75, 76, 77) categorized by industry. These are shown in Table 11. The frequencies of disabling injuries, (defined as disabling beyond the day of the accident) are also listed there as a matter of interest; we see that mortality is not the only important aspect of occupational risk.

If we assume that these accidents occur with equal probability at all ages between 18 and 64, the data in the bottom lines of Table 2 can be used by multiplying all values by the ratio of the mortality rates in Table 11 to the 10×10^{-5} assumed in Table 2. The total losses of life expectancy upon entering the occupation, $\Delta E(18–\infty)$ are listed in the last column of Table 11 for males. Other values of

Table 11. *Occupational accidents*

Industry type	Workers (000)	Deaths per 100,000	Disabling injuries (000)	Days lost life exp.
All industry	87,800	14.7	2200	74
Trade	20,300	6	400	30
Manufacturing	19,000	8.7	470	43
Service	20,800	9.7	410	47
Government	14,900	11	320	55
Transportation and Public Utilities	4800	32.7	190	164
Agriculture	3500	55.3	190	277
Construction	3700	60.3	210	302
Mining, Quarrying	800	65.7	40	328
Radiation (0.5 rem/yr)			0	40

$\Delta E(M, Q)$ and values based on sex and race may be scaled proportionately from Table 2.

The last line of Table 11 gives the occupational risk of radiation exposure in the nuclear industry based on an average whole body exposure of 500 mrem/year. It is evident that this risk is not large relative to other occupational risks. Some occupational radiation exposures are as much as ten times larger than this average, but it should be recognized that the risks listed for other occupations are also averaged rather than risks to those most exposed.

Many occupations involve mortality risks other than accidents. There may be exposure to toxic chemicals or dusts, unusual temperatures, or other environmental factors which cause delayed deaths not classified as accidents.

There have been at least two studies of mortality ratios for various industries, one based on U.S. mortality in the year 1950 by U.S. Public Health Service (PH62), and a study of 1955–64 experience with industries holding group life insurance published by Society of Actuaries (So67). Their data are listed in Table 12; in both of these studies, statistical accuracies are rather poor, but we take the average between them and assume that these mortality ratios apply at all ages between 18 and 64 to calculate effects on life expectancy. Our results are listed in the last two columns of Table 12 for loss of life expectancy up to age 70 and for total loss of life expectancy.

Table 12. Mortality ratios in various U.S. industries from studies by U.S. Public Health Service and Society of Actuaries

Industry	Workers in 1965 (000)	Mortality ratios USPHS	S of A	Years added life exp 18–70	18–∞
Agriculture		0.96	0.87	+0.5	+0.7
Coal mining	142	1.42	1.53	−2.2	−3.2
Other mining	200	1.08	1.32	−0.9	−1.4
Oil, gas recovery	282	0.98	1.14	−0.3	−0.4
Construction	3200	1.18	1.22	−0.9	−1.4
Mfg—metals, machinery	6000	0.88	1.12	0	0
clothing	1350	0.74	0.70	+1.5	+2.1
rubber, chemicals, etc	1900	0.86	0.92	+0.6	+0.8
paper, printing	1600	0.90	1.05	+0.1	+0.2
Railroad	737	1.21	1.29	−1.2	−1.8
Motor freight	965	1.71	1.23	−2.2	−3.2
Airlines	230	1.02	0.95	0	+0.1
Communication	880	0.81	0.80	+0.9	+1.4
Wholesale trade	3260	0.66	1.00	+0.8	+1.3
Retail trade	9300	1.1	0.80	+0.2	+0.4
Finance, insur., real est	3040	0.97	0.84	+0.5	+0.7
Business	1070	0.98		+0.1	+0.2
Medical services	2160	0.93		+0.3	+0.5
Education services	940	0.59		+2.1	+3.1
Local transit			1.37	−1.7	−2.5
Elec.—gas			1.10	−0.5	−0.7
Fireman			1.52	−2.3	−3.5
Policemen			1.42	−1.9	−2.8
Post office		0.83		+0.9	+1.3

We see from Table 12 that coal mining is perhaps the most dangerous major occupation, costing an average of over three years of life expectancy. A breakdown on causes of death indicated that coal miners have a large excess of respiratory disease, but the most important factor is accidents, including even automobile accidents. Apparently the life of a miner is not conducive to being careful even when outside of mines.

Since Table 12 is calculated under the assumption that ratios return to unity immediately after retirement, it under-estimates the effects; surely exposure to toxic substances between ages 18 and 64 can cause premature death at later ages. Another problem with Table 12 is that it lumps all workers in an industry into a single group, including management, workers and office personnel. But the most important difficulty with Table 12 is that it is heavily influenced by socioeconomic factors. These are discussed in the next section.

SOCIOECONOMIC FACTORS

Information on mortality ratios by job type is available from the Public Health Service study of mortality in the year 1950 (PH62a; Me75). Occupations are grouped as:

I. Professional (4%, 0.5%)

II. Technical, administrative, managerial (10%, 3%)

III. Proprieters, clerical, sales, skilled (40%, 14%)

IV. Semi-skilled (24%, 30%)

V. Unskilled (8%, 31%).

The percentage of whites and non-whites that are in each group is given in parenthesis.

Results on life expectancies for these groups relative to the U.S. average are listed in the top lines of Table 13 for whites only. We see that the differences between Classes I and V approach 4 yr. If non-whites had been included, they would have been twice as large.

Data from England and Wales (Re71) indicate an even larger spread among occupational classes. The mortality ratios (to the

Table 13. ΔE(M, Q), losses in life expectancy in years from average for various socioeconomic, education and racial groups

Group	Age range 0–55	55–70	70–85	85–∞	0–∞
Occup. Class: I	−0.57	−0.13	−0.26	−0.23	−1.7
II	−0.39	−0.23	−0.48	−0.44	−1.8
III	−0.27	+0.08	+0.17	+0.14	−0.23
IV	−0.09	−0.06	−0.13	−0.11	−0.40
V	+0.59	+0.19	+0.36	+0.30	+2.0
Educ.—Fem.—College	−0.12	−0.21	−0.65	−0.90	−2.2
high school	−0.07	−0.13	−0.37	−0.48	−1.2
8 years	−0.05	+0.09	+0.26	+0.31	+0.79
< 8 years	+0.19	+0.33	+0.92	+0.99	+2.7
Educ.—Male—College	−0.28	−0.49	−1.0	−1.0	−2.9
high school	−0.04	−0.06	−0.13	−0.11	−0.33
8 years	−0.07	+0.13	+0.25	+0.21	+0.64
< 8 years	+0.18	+0.31	+0.60	+0.48	+1.5
Race(Cal)—White	−0.10	−0.04	+0.20		−0.08
Negro	+2.0	+0.47	+0.50		+5.2
Japanese	−1.3	−0.88	−0.65		−5.4
Chinese	−1.2	−0.14	+0.16		−2.4
Insured males	−0.29	−0.44	−0.37		−2.0
Insured females	−0.10	−0.23	−0.23		−1.3

whole population) averaged over ages 15–64 are listed in Table 14. We see that the effects are very similar between men and their wives, which indicates that we are dealing more with socioeconomic factors than with occupational risks.

It is interesting in this regard to note that *causes* of death also relate to occupational class. Data on this for U.S. white males are shown in Table 15. We see that Class I males are much less likely than Class V to die from tuberculosis, influenza, and accidents, and there are strong tendencies of this type for cancer, cirhosis of liver, and suicide. Data from England and Wales are qualitatively similar and indicate that trends for wives also follow the same patterns, including the lung cancer and influenza trends. The fact that some diseases in Table 15 do not show a dependence on occupational class would seem to indicate that medical care is not an important factor, but there are data (Me77a) on salary dependence listed in the last column of Table 15 which indicate that money is an important factor. Low salaried individuals have a 30% higher overall mortality rate and at least a 50% higher mortality rate from lung cancer, cerebrovascular disease, influenza, pneumonia, and accidents than those with medium or high salaries.

Table 14. Mortality ratio averaged over ages 20–64 in U.S. and 15–64 in England and Wales for various occupational classes (for U.S. in 1950; England and Wales 1959–1963)

Population group	Occupational class Class I	Class II	Class III	Class IV	Class V
U.S. total males	0.82	0.85	0.97	1.00	1.53
U.S. white males	0.83	0.84	0.96	0.97	1.20
Eng.—Wales males	0.76	0.81	1.00	1.03	1.43
Eng.—Wales females					
married	0.77	0.83	1.02	1.05	1.31
single	0.83	0.88	0.90	1.08	1.21

Another line of evidence connecting life expectancy with socioeconomic factors comes from the dependence of mortality ratios on educational attainment. Data on this are available (Ki68) for both male and female divided up into the following four groups:

(A) One or more years of college
(B) High school graduates
(C) Elementary school graduates
(D) Less than 8 years of schooling.

Single mortality ratios are given for ages 25–64, but it seems most reasonable that the factors that cause differences should continue to operate for the remainder of life in this age range so we have assumed this to be the case.

Results are included in Table 13. We see that the extreme differences in educational attainment give over 4 yr difference in life expectancy. The differences are even larger for women which again indicates that occupational hazards are not a dominant factor.

There are data on mortality ratios for business executives listed in "Who's Who in

Table 15. Mortality ratio for various causes of death for U.S. white men, age 20–64, by occupational class

Cause of death	Occupational class Class I	Class II	Class III	Class IV	Class V	Low/med/high salary
All causes	0.82	0.83	0.96	0.97	1.21	1.3
Tuberculosis	0.36	0.40	0.69	1.03	1.58	
Cancer—all	0.89	0.91	1.06	1.04	1.16	1.2
lungs, bronchus	0.81	0.91	1.16	1.15	1.20	1.5
Diabetes	0.98	0.99	1.10	0.88	0.90	1.3
Cerebrovascular	0.87	0.79	0.89	0.80	0.94	1.5
Arteriosclerotic	1.15	1.09	1.16	1.00	1.03	[illegible]
Influenza, pneum.	0.57	0.51	0.73	0.95	1.53	1.7
Cirhosis of liver	0.90	0.88	1.07	1.22	1.58	
Accidents	0.50	0.68	0.82	1.07	1.73	1.5
Suicide	0.90	0.86	0.99	1.02	1.47	1.8

America" in 1950–51 followed over the next decade, and on executives of companies included in the 1957 Fortune list of 500 industries with largest sales, followed over the next 15 yr (Me74). These are converted to increases of life expectancy relative to the average white male in Table 16. We see that these men, who are near the the top of the socioeconomic ladder, live nearly 5 yr longer than average—twice the largest increases for those in the broader top classes considered in Table 13.

Top political leaders do not do nearly as well. The excess longevity of some groups (Me70, 71b, 71c, 75a, 76) are listed in Table 17. We see that Governors, Congressmen, Senators, and even Supreme Court Justices (who would seem to lead less pressured lives than the others) do not enjoy the increased life expectancy of the highest socioeconomic classes, and that being President of the United States in this century is one of the most dangerous jobs available. The statistics for this last group are somewhat distorted by the assassination of John F. Kennedy at a relatively young age; but even without this case, life expectancy of twentieth century presidents has been 3.0 yr less than for average white males.

Mortality ratios are available on a rather different group, baseball professionals, who played in the major leagues for 5 or more years (Me75b). Excesses in their life expectancy relative to average white males (most of those who have died played in the era when major league players were white) are given in Table 16. This group, which is characterized by excellent physical condition at younger ages and perhaps better than average economic status, typically lives about 3 yr longer than average.

Table 16. $\Delta E(M, Q)$, increase of life expectancy in years relative to all white males for special groups

Group	Age range				
	40–55	55–70	70–85	85–∞	40–∞
Corporation executives	0.16	0.81	1.8	2.2	4.7
Business executives	0.25	1.1	1.2	0.15	4.3
Baseball players	0.13	0.57	1.0	0.96	2.9

Table 17. Average lifetime of twentieth century U.S. political leaders as compared with contemporary U.S. white males

Office	Additional longevity (yr)
Presidents	−5.1
Mayors of New York City	−1.3
Congressmen	+0.2
Senators	+0.4
Governors	+0.5
Supreme Court Justices	+1.4

It is evident from Table 1 that there are important racial differences in life expectancy between whites and non-whites, and it is not easy to separate these from socioeconomic factors. Some evidence on this question may be obtained by considering a breakdown of non-white races. Data are available (Me74a) on this from California which has a sizeable population of Chinese and Japanese. Results for life expectancy are included in Table 13. We see that the differences between Japanese and Negros exceed 10 yr, which is far larger than the differences due to socioeconomic factors we have identified. It would seem that there truly are important purely racial differences of a few years in life expectancy.

One possible indicator of socioeconomic status for which data are available is insurance coverage. Physical examinations connected with purchase of insurance would distort data for the first few years, but their effect should be inconsequential 15 yr later; in fact, mortality statistics for holders of individual insurance policies are quite similar to those having group insurance, which requires no physical examination (Me71a). However, both of these categories have considerably lower mortality rates than average. Data are available for white males and white females, and results on life expectancies calculated from them are included in Table 13. It seems that just being the type of person who buys life insurance means that one will probably live 1.3–2 yr longer than average.

MARITAL STATUS

One of the most important factors correlated with mortality rates is marital status. Data are available for white and non-white males and females on mortality rates at various ages when single, married, divorced, and widowed (NC70). The losses of life expectancy relative to those who are married are shown in Table 18. The marital status for

Table 18. $\Delta E(M, Q)$, *loss of life expectancy in years of unmarried relative to married people*

Unmarried group	Age range				
	20–55	55–70	70–85	85–∞	20–∞
Single—white male	1.50	0.97	1.47	1.04	6.04
non-W male	3.30	1.20	1.60	1.51	8.79
white female	0.56	0.12	0.90	1.45	3.21
non-W female	1.12	0.50	2.23	3.27	6.01
Widowed—white male	3.60	1.29	1.66	1.38	9.99
non-W male	6.59	2.59	2.48	2.18	15.1
white female	0.95	0.29	1.21	1.66	4.66
non-W female	1.97	1.39	3.07	3.75	9.51
Divorced—white male	3.68	2.42	2.30	1.44	12.4
non-W male	4.55	2.42	2.36	1.70	12.2
white female	0.89	0.39	0.96	1.22	4.47
non-W female	0.82	0.59	1.98	2.83	5.30

an individual changes with time, whereas Table 18 assumes that it remains constant over the age range indicated. It should therefore be used with some caution over very large age ranges. It is nevertheless clear that not being married is one of the greatest risks people voluntarily subject themselves to. It is also interesting to note that men apparently suffer much more than women from being unmarried.

GEOGRAPHY

Average lifetimes vary considerably among the states of the United States. To avoid racial differences, we list data for whites only in Table 19 (NC75). Since we have shown that economic status has an important effect on life expectancy, we also list per capita income relative to the U.S. average (Ce75). It is clear that economic status can explain only a very small part of the 3.5 yr difference between the extremes in Table 19. The largest differences are between rural northern states and rural southern states, which suggests that geography plays an important role.* This may be correlated with differences between northern and southern Europe which are of about the same magnitude (Norway-73, Sweden-74, Denmark-72 vs Italy-70, Greece-69, Spain-70), although there may be racial differences in the European situation. In any case, it is difficult to escape the conclusion from Table 19 that moving from one state to another can change one's life expectancy by 1 or 2 yr.

Table 19. *Average lifetime* (1969–71) *for white males and average per capita income* (1970) *in various states*

State	Average lifetime	Per capita income	State	Average lifetime	Per capita income
		U.S. aver.			U.S. aver.
ND	73.09	0.805	MD	71.55	1.09
MN	73.04	0.968	NY	71.48	1.19
SD	72.96	0.782	MI	71.47	1.05
UT	72.95	0.811	OH	71.44	1.01
NB	72.89	0.955	DE	71.42	1.14
CT	72.88	1.241	IN	71.32	0.95
KS	72.87	0.973	AZ	71.30	0.92
IA	72.64	0.95	IL	71.23	1.14
WI	72.64	0.96	TN	71.22	0.79
OR	72.20	0.94	NH	71.21	0.97
CO	72.18	0.97	PA	71.16	1.00
FL	72.16	0.94	NC	71.08	0.82
RI	72.07	1.00	MT	71.01	0.88
MA	72.01	1.10	NM	71.00	0.78
ID	71.99	0.83	ME	70.93	0.83
WA	71.95	1.02	AL	70.93	0.74
CA	71.95	1.13	LA	70.70	0.78
OK	71.85	0.85	KY	70.66	0.79
NJ	71.84	1.19	DC	70.64	1.27
TX	71.74	0.91	GA	70.62	0.85
AR	71.71	0.73	MS	70.50	0.66
VT	71.62	0.84	SC	70.32	0.75
VA	71.61	0.94	WV	69.78	0.77
MO	71.57	0.95	NV	69.43	1.15

It is interesting to note that risks of mortality from a given disease also vary substantially from state to state. For example, annual mortality rates per 100,000 population from cancer are 190 in the northeast (199 in RI) vs 155 in the south central states (145 in TX) [and 123 in the mountain states (91 in UT)], whereas for cerebrovascular diseases, the rates are 95 in the northeast (87 in NY) and 120 in the south central states (Ce75). Variations in mortality from accidents are especially large; rates are 91 in NM and WY vs 38 in NY, NJ and CT.

There is a statement in the literature that people in rural areas live 5 yr longer than those in urban areas (Te58). Some effort was made to check this, but without success. In Table 19 we see that life expectancy for whites in District of Columbia, which is entirely urban, is not more than 1 yr less than in surrounding rural states. National Center for Health Statistics does not compile data on a rural vs urban basis. Their data on metropolitan areas (which include some rural components) are not grossly different from those for non-metropolitan areas (which in-

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*The per capita incomes listed in Table 19 are for the entire population rather than for whites only. So for rural southern states which have large populations of low income non-whites, per capita incomes in Table 19 are considerably lower than for whites. This is further evidence that economic status does not explain the differences in life expectancy.

clude small cities). Table 12 indicates that farmers live about 0.7 yr longer than average. There is some indication that people in suburbs live longer than those in urban or rural areas, although socioeconomic factors would be relevant here. It seems propable that urban–rural differences do not cause more than 1 yr difference in life expectancy.

ARMED FORCES

Combat duty in wartime is clearly a dangerous situation. If we assume that the average member of the Armed Services killed in Vietnam died at age 25, the average loss of life expectancy from being sent to Vietnam was as given in Table 20. Deaths in the armed forces are especially notable for the large fraction of lost life expectancy that occurs in the prime years of life. The ratio of death rates in Vietnam to average death rates for men of the same age in this country was about 10 for the army, 5 for the navy, 20 for the marines, and 3 for the air force.

Table 20. Loss of life expectancy for members of the U.S. Armed Forces sent to Vietnam

Branch	Lost life expectancy
Army	1.1 yr
Navy	0.5
Marines	2.0
Air force	0.28

CATASTROPHIC EVENTS (NR75)

The news media generally give extensive coverage to incidents involving large loss of life, and the public has a considerable awareness of such risks. The effects of these risks in terms of average lost life expectancy are listed in Table 21. Hurricanes have caused about 90 deaths per year in the U.S. during this century. If an average fatality corresponds to 35 yr of lost life expectancy, the average American loses 0.5 days of life due to this hazard. Tornadoes have caused an average of 118 deaths/year in recent times, and there have been about 1100 deaths from earthquakes in this century (2/3 of them in the 1906 San Francisco earthquake). An average of 200 people per year die in airline crashes in this country, and for every ten of these, there is one person on the ground killed. An average of 35 Americans die each year in large explosions (resulting in 8 or more fatalities). Dam failures have caused an average of about 35 fatalities/year in U.S., but estimates of potential dam failures indicate that a long term average may be more than twice that many. Large fires with 10 or more fatalities occur about once a year in the U.S., accounting for only 2% of the total effects of all fires and burns given in Table 4. There is frequently a great deal of publicity over accidental releases of poisonous gases, but rarely are there any deaths involved. Estimates of potential catastrophes of this type indicate that they may cost the average American about 0.1 days of life. The risk of dying as a result of a nuclear power plant accident if we had all nuclear power in this country would reduce life expectancy by 0.5 hr according to the Rasmussen Study, or by 2 days according to Union of Concerned Scientists (UC77); only a few percent even of these fatalities would occur within the first few months, and the remainder would represent an undetectable increase in cancer risks over the following half century.

Table 21. Loss of life expectancy due to catastrophic events, averaged over the U.S. population

Catastrophic events	Total lost life expectancy (days)
Hurricanes	0.5
Tornadoes	0.5
Earthquakes	0.1
Airline crashes (passengers)	1.0
Airline crashes (people on ground)	0.1
Major explosions	0.2
Dam failures	0.5
Major fires	0.5
Chemical releases	0.1
Nuclear reactor accidents:	
within following 50 years	0.02–2*
noticeable, within first year	0.0004–0.1*

*Assumes all U.S. power nuclear. First figure from Rasmussen Report; second figure from Union of Concerned Scientists.

There seems to be some support for the idea that the important thing about catastrophic events is not the average risk from them, but how frequently they occur. The argument here is that public morale is the important issue, there being no hope of educating people to understand risks. Estimates of the average number of years between events of a given type causing 1000 or more fatalities are listed in Table 22. The pessimistic values for nuclear accidents are from Union of Concerned Scientists (UC77).

Table 22. Average number of years between catastrophes of given type which cause 1000 or more fatalities

Type catastrophe	Av. years between
Hurricanes	20
Earthquakes	40
Air pollution episodes	20
Dam failures	50
Explosions	150
Fires	200
Poison gas releases	1000
Airline crash	3000
Nuclear plants (400 GW)	
fatalities within months	200,000–1000*
fatalities within 50 yr	300–10 (?)*

*First numbers are from Rasmussen Study; second numbers from Union of Concerned Scientists. The 10 (?) is based on their estimate of one meltdown every 5 yr; to produce many fatalities, such a meltdown must be followed by a containment failure, the probability of which they do not estimate but we take their estimate to be 50%.

ENERGY PRODUCTION

There is a widespread impression that even if there were no fuel shortages, we must reduce our use of energy to avoid catastrophic environmental problems. Table 23 lists estimates of the number of fatalities per year in the U.S. caused by generation of energy. Many of these estimates are from Co76. The coal transport estimate is from Sa74. The mortalities from gas and oil induced fires are estimated as 2 and 10% respectively of all deaths from fires. The asphyxiation deaths from gas are estimated as a third of all asphyxiations, most of which are from carbon monoxide which we do not include here. Hydroelectric dam failure estimates are from Table 21 assuming 40% of large dams are hydroelectric. Gas explosions are from Wi74.

The 24 days of lost life expectancy in Table 23 is relatively trivial compared to a great many of the risks we have been discussing. We may therefore conclude that energy generation is something less than a major threat to our health and safety.

Table 23. Fatalities per year among public due to energy generation

Source	Fatalities per yr	Av. years lost	Days reduced life exp.
(A) Coal			
air pollution	10,000	10	11.5
transport accidents	300	35	1.0
(B) Oil			$\Sigma = 12.5$
air pollution	2000	10	2.2
fires	500	35	2.0
(C) Gas			$\Sigma = 4.2$
air pollution	200	10	0.2
explosions	100	35	0.4
fires	100	35	0.4
asphyxiation	500	25	1.5
(D) Hydroelectric			$\Sigma = 2.5$
dam failures	50	35	0.2
(E) Nuclear (400 GW)			$\Sigma = 0.2$
routine emissions	8	20	0.018
accidents	8	20	0.018
transport	< 0.01	20	—
waste	0.4	20	0.001
plutonium toxicity	< 0.01	20	—
			$\Sigma = 0.037$
(F) Electrocution	1200	35	5.0
Grand total			24

TECHNOLOGY

One sometimes hears the opinion expressed that technology is an overall threat to our health and safety. The simplest test of this is to compare life expectancies in technologically developed and undeveloped countries; this is done in Table 24 (Eh72). We see that technology can clearly be credited for several decades of increased life expectancy.

Another approach to this question is to recognize that technology produces wealth, and we have extensive evidence that wealth increases life expectancy. Losses of life expectancy due to technology may be patterned after our treatment of risks in production of energy. Energy production is well recognized as our most polluting single industry, and it probably accounts for at least 30% of all fatality producing industrial pollution. We may therefore estimate that all of the pollution produced by industrial technology probably does not reduce our life

Table 24. Life expectancies in various regions and countries

Region or country	
United States, Canada	71
Australia, New Zealand	71
Europe	70
United Kingdom, France, Germany	71
Poland, Rumania	68
Yugoslavia	65
Portugal	64
Latin America	60
Argentina	67
Mexico	61
Peru	57
Haiti	40
Asia	50
Japan	71
Turkey	55
India	45
Indonesia	42
Africa	43
Egypt	52
Kenya, Ghana	42
Congo	40
Chad, Upper Volta, Ivory Coast	32
Guinea	30

expectancy by more than 100 days. The added wealth resulting from it clearly saves us many times that number of days.

METHODS FOR REDUCING RISKS

A few methods for reducing risks without making major sacrifices are listed in Table 25. It is estimated that using seat belts or air bags would avert about a quarter of all motor vehicle fatalities. The effect of car size is from statistics that fatalities per vehicle-year are more than twice as high in small cars as in large cars (II75). It has been estimated that smoke alarms in homes would eliminate between a third and a half of all deaths due to fires. According to the Walton Report (Wa76), a PAP test has one chance in 4000 of averting death from cervical cancer, and each life saved adds about 40 yr of life expectancy.

Table 25. Days of life expectancy added by various actions

Action	Added life exp. (days)
Using seat belts	50
Installing air bags in car	50
Buying larger cars*	50
Smoke alarm in home	10
Training family in resuscitation	≫100
Annual PAP test	4

*Standard rather than sub-compacts, or large rather than standard.

PRIORITIES AND PERSPECTIVE

In Table 26 we have assembled many of the values of ΔE developed in this paper and listed them in order of decreasing ΔE. We have combined and averaged some categories to reduce complexity.

To some approximation, the ordering in Table 25 should be Society's order of priorities. However, we see several very major problems that have received relatively little attention (at least from the health standpoint) whereas some of the items near the bottom of the list, especially those involving radiation, receive a great deal of attention. Perhaps a few specific suggestions are in order here:

1. To reduce the number of unmarried adults, government agencies might organize computer dating services. More sociological research on that problem might be stimulated. Favorable publicity on the advantages of marriage might be encouraged.
2. To control overweight, calorie content of foods could be printed on labels to make people aware of them. Publicity on dangers of overweight could be disseminated.
3. Detailed studies could be undertaken aimed at understanding differences in life expectancies in various states.
4. Less attention should be paid to radiation hazards, catastrophes, saccharin, etc.

Table 26. Loss of life expectancy (ΔE) due to various causes

Cause	days
Being unmarried—male	3500
Cigarette smoking—male	2250
Heart disease	2100
Being unmarried—female	1600
Being 30% overweight	1300
Being a coal miner	1100
Cancer	980
20% Overweight	900
< 8th Grade education	850
Cigarette smoking—female	800
Low socioeconomic status	700
Stroke	520
Living in unfavorable state	500
Army in Vietnam	400
Cigar smoking	330
Dangerous job—accidents	300
Pipe smoking	220
Increasing food intake 100 cal/day	210
Motor vehicle accidents	207
Pneumonia—influenza	141
Alcohol (U.S. average)	130
Accidents in home	95
Suicide	95
Diabetes	95
Being murdered (homicide)	90
Legal drug misuse	90
Average job—accidents	74
Drowning	41
Job with radiation exposure	40
Falls	39
Accidents to pedestrians	37
Safest jobs—accidents	30
Fire—burns	27
Generation of energy	24
Illicit drugs (U.S. aver.)	18
Poison (solid, liquid)	17
Suffocation	13
Firearms accidents	11
Natural radiation (BEIR)	8
Medical X-rays	6
Poisonous gases	7
Coffee	6
Oral contraceptives	5
Accidents to pedalcycles	5
All catastrophes combined	3.5
Diet drinks	2
Reactor accidents—UCS	2*
Reactor accidents—Rasmussen	0.02*
Radiation from nuc. industry	0.02*
PAP test	−4
Smoke alarm in home	−10
Air bags in car	−50
Mobile coronary care units	−125
Safety improvements 1966–76	−110

*These items assume that all U.S. power is nuclear. UCS is Union of Concerned Scientists, the most prominent group of nuclear critics.

RISKS IN INDIVIDUAL ACTIONS

In on-the-spot decision making, one must consider the risk in a single individual action. If we assume linearity, the values listed in Table 27 are obtained for smoking, ingesting calories, and using saccharin. The risk of crossing a street is based on pedestrian fatalities and the assumption that the average person crosses 5 streets per day. The very large values are from far-reaching decisions having effects for an extended period of time, so they should probably not be considered as on-the-spot decisions.

It may be noted that smoking a cigarette has the risk of 7 mrem of radiation, and an overweight person eating a pie a-la-mode runs a risk equal to that of 35 mrem.

Table 27. Risks in individual actions

Individual action	Minutes life expectancy lost
Smoking a cigarette	10
Calorie-rich dessert	50
Non-diet soft drink	15
Diet soft drink	0.15
Crossing a street	0.4
Extra driving	0.4/mile
Not fastening seat belt	0.1/mile
1 mrem of radiation	1.5
Coast to coast drive	1000
Coast to coast flight	100
Skipping annual PAP test	6000
Moving to unfavorable state	800,000
Buying a small car	7000
Choose Vietnam army duty	600,000

VERY HAZARDOUS ACTIVITIES

Some activities, like automobile racing or tight-rope walking, are generally viewed as extremely hazardous; we here convert some of these to loss of life expectancy. If such an activity involves mortality risk of 1/1000 per year, and the average victim loses 35 yr of life, $\Delta E = 0.035$ yr or 13 days. For other risks, ΔE scales proportionally.

Information on these is given in Table 28, with the data derived from statistics for recent years (Me74b; Me76a). The "professional motorcycle racers" refers to members of American Motorcycle Assn. Professional aerialists include tightrope walkers, trapeze artists, aerial acrobats, and high pole balancers. "Hard-hat" divers are deep sea divers who use a rubber suit, a metal helmet, heavy weights, and a hose to an air pump on the surface; decompression sickness is their major hazard. Smoke stack construction refers to bricklayers and masons engaged in building smokestacks; their major hazard is falling.

Table 28. Risks in hazardous activities (Me74b; Me76a)

Occupation	Participants	Recent av. deaths/yr	ΔE/yr of participation
Championship auto racing	5000	1.9	5 days
Automobile drag racing	145,000	7.4	0.7
Go-cart racing	18,000	0.6	0.4
Midget auto racing	2800	2.2	10
Motorcycle racing	115,000	22	2.5
Professional motorcycle racers	4000	6	20
Snowmobile racing	15,000	2	1.9
Sports car racing	11,000	3.3	4
Sprint car racing	8500	8.2	13
Stock car racing	26,000	10.2	5
Figure 8 stock car	2000	0.2	1.3
Professional aerialists	300	0.12	5
Navy frogmen	200	1	65
Navy "hard-hat" divers	1150	0.5	6
Commercial "hard-hat" divers	3500	11	40
Abalone divers	170	2	150
Sponge divers	100	0.17	22
Smoke-stack construction	100	1	130

Much of these data are crude, but they should be valid to within a factor of 3 or so, and as an average they should be somewhat better. It would seem that these activities rarely would reduce life expectancy by more than 5 days or so per year of participation, so even 30 yr of participation would not be as dangerous as gaining 10 lb of body weight.

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Attachment 3

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* AMC does not necessarily endorse every statement made in this document. We have referenced certain materials from this document in our written and oral comments and it is attached hereto for the reader's convenience.

SOCIETY'S VALUATION OF LIFE SAVING
IN RADIATION PROTECTION AND OTHER CONTEXTS

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Abstract

Various situations are described in which Societal action may be interpreted as a dollar value placed on averting a human fatality, and numerical values are derived in each case. Situations included are a variety of medical screening and medical care programs and of automobile and highway safety measures, food for overseas relief, air pollution control, fire prevention, industrial safety, aircraft safety, and several radiation related activities including standards for radium in drinking water, medical X-ray equipment, radwaste systems in nuclear plants, and defense and civilian high level waste management. Values varying from a few thousand dollars to hundreds of millions of dollars per fatality averted are obtained. An attempt to derive data of this type from polling is described. The problem of discounting when money is spent now to save lives far in the future (as with nuclear waste) is discussed.

It is concluded that nearly all of the vast variation in the results is unjustified and represents a need for educating the public, especially in the area of radiation protection.

Introduction

The principal purpose of radiation protection is to save lives, and the principal limitations on its capability of doing so derive from the costs involved. Almost any operation can be done by remote control, and the shielding can almost always be increased to reduce radiation exposure. Where do we stop? The traditional answer to this question lies in application of the concept of maximum permissible dose, but that is, in many ways, a "cop-out." The only logical answer is to stop where the costs exceed the benefits.

This introduces a very difficult element into the decision making. The costs are usually in dollars, while the benefits are principally in lives saved, whence the comparison between costs and benefits can only be made quantitatively if we are willing to assign a dollar value to a human life. That is the problem addressed in this paper.

Assigning a dollar value to a human life appears intuitively to be an immoral and repugnant subject, but actually we all do it frequently. For example, when we buy low priced tires rather than the type that cannot blow out, or when we decide not to have frequent medical check-ups, we are placing a dollar value on our own lives and even on the lives of our loved ones. The value of life saving is also an implicit element in public decision making. It is well recognized that divided highways bordered with gently sloping terrain free of obstacles that may provide targets for hard collisions are much safer than typical roads and hence can save lives, but we build only a small fraction of our highways with those features, only to save money. There are many ways in which medical care could be improved by expenditure of public funds, and surely these would save lives.

Perhaps the moral position in considering a dollar valuation of human lives is improved if we recognize that monetary costs largely represent human labor, both directly and indirectly in that the costs of materials largely represent the costs of labor to derive them —when we mine a mineral we don't pay the earth for it. The question we are really addressing then, is how many man-hours or life-times of labor should be devoted to extending one person's life.

It would clearly be inappropriate for a scientific paper to recommend a value to be placed on a human life in radiation protection contexts. However, it does appear relevant to decisions in that area to recognize the value adopted by Society in other contexts. In this paper we therefore attempt to assemble the available information on that question and to develop further estimates wherever possible.

The valuation of human life as an element in cost-benefit analysis is not a new subject; in fact there is a rather large body of literature on that topic (Fr-65, Sc-68, Mi-72, Ze-75, Li-75, Li-76, Co-76, Ze-76, Fi-77, Kr-77, Li-78, Rh-78, to cite a few examples) largely developed by economists and sociologists. In fact this literature often does not stop short of making recommendations on the valuation. Some of the criteria they have used for this purpose are expected future earnings (complete with discounting as for interest, and in one case even a correction for funeral expenses), court judgements, and insurance coverage. In a few cases this literature is aimed at pointing out specific "bargains" or "over-payments" in the enterprise of spending money to save lives.

The National Safety Council (Na-75) even provides a dollar cost of a death — $43,000 in 1968, $97,000 in 1974, $110,000 in 1975 — which is widely used in decision making on highway modifications. Other values used (Ge-76) are $140,000 and $201,000 in 1970-71. In this paper, we refrain from such activities and confine our attention to collecting and deriving information. We do this by identifying situations in which money can be spent to save lives but in which the decision of Society is to do so to a significant extent, but not in a massive way.

In some cases, saving lives requires human time and effort as well as money, as for example in medical screening programs where subjects must appear for examinations or tests. In such cases we attempt to add the cost of this inconvenience, based on a subjective estimate of how much you would expect to pay a person for expending an equivalent amount of time and effort for some other purpose. In the above case we apply an "inconvenience cost" of $5 to appear for an examination taking only a few minutes. In many cases throughout our treatment it is necessary to make estimates of this general type, but they are always presented in such a way that the reader can substitute his own estimates to derive his own results.

There are also many cases where it is necessary for us to make judgements. For example in the early 1970s it became clearly recognized that lives could be saved at a cost in the range $5000 each by introducing in cities an advanced ambulance service with well-trained paramedics and elaborate equipment. Within a few years, this was implemented in all large cities. It is our judgement that the fact that it was not implemented earlier does <u>not</u> indicate that life was valued at less than $5000, but rather that the cost-benefit relationship was not recognized. As a counter example the fact that after more than two decades of experience with PAP tests for cervical cancer, with data available on several local successful programs, the fact that only 50% of those at risk receive annual tests is, in our judgement, an indication that Society is not willing to spend the money to greatly increase the coverage. In borderline cases of this type, the facts are presented and the reader is, of course, free to substitute his own judgements for ours.

Since the data we present are from different time periods, we have made at least a crude effort to correct costs for inflation. These corrections are minimized if we use 1975 dollars, so for convenience, we have converted all costs to those terms.

Because of the many estimates involved, few of our results can be assigned high accuracy. We feel that most of them are accurate to within 50%, although this may be over-optimistic in many cases. Where there are uncertainties, we have tended to accept higher valuations in medical areas where the valuations seem to be relatively low.

With this introduction, we now embark on a series of case studies in which we judge that a dollar value of a human life is implicit. The results are summarized in Table 1 as both the cost per fatality averted, and the cost per 20 years of life expectancy gained. In many cases, the conversion from the former to the latter involves a crude estimate, but this is not an important source of error.

Case Studies

A. Medical areas

Perhaps the most obvious area in which money can be spent to save lives is in medical care. Large increases in life expectancy have been achieved during this century as a result of improved medical care, and there is abundant evidence that nations with poor medical care have lower life expectancy.

We present evidence here on several medical care programs that could save lives but which are not being widely implemented largely because of cost considerations. For cancer screening programs we have ignored treatment costs because they would probably be at least as great if the cancer were later discovered from symptoms as if it is detected early by screening.

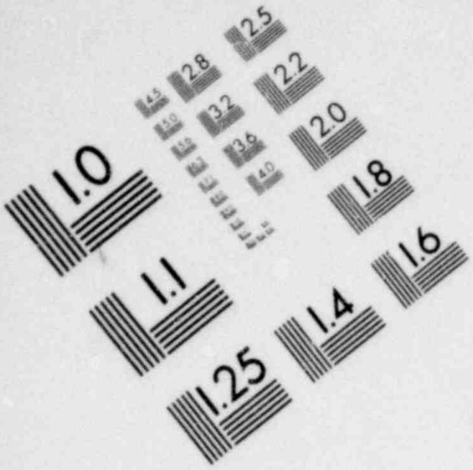
1. Cervical Cancer Screening

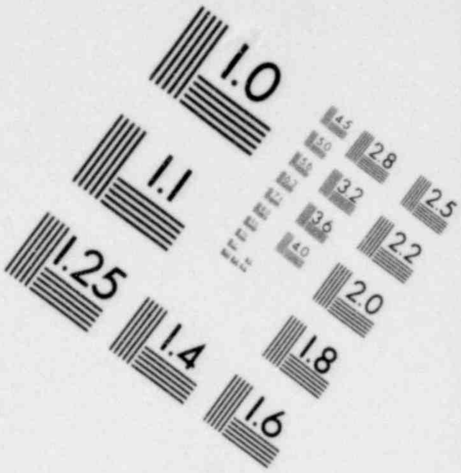
Cervical cancer afflicts mature women, bringing death to one U.S. female in 10,000 each year. It is readily detected by a test developed by Papanicolaou (PAP smear), and if detected at an early stage, can almost always be cured. PAP tests became widely available in the 1950s, but by 1968, there was no state in which as many as 20% of all women of the susceptible age were tested (Cr-74), although by 1977 the percentage screened rose to about 50% (Ga-77). Local screening programs were set up in many places thorughout the world, and these are useful for cost-benefit analysis. They also demonstrate the feasibility of achieving at least 90% coverage of the population at risk (Wa-76).

In a study of a Mayo Clinic program in Olmstead County, Minnesota, during 1960-67, Dickinson (Di-72) reported that the program cost \$182,000 for 51,700 PAP smears, and detected 184 cases; among these the cure rate was 91% vs 74% for cases detected without a screening program, which corresponds to saving (.91-.74) x 184 = 31 lives. The cost was thus \$182,000/31 = \$5800 per life saved. The average life expectancy of those cured was 40 years. If we apply an inflation factor of 1.5, and assume that the inconvenience to the person taking the test is worth \$5, the corrected cost per life saved becomes \$17,000.

In a study of screening programs in Aberdeen, Scotland during 1971, Thorn et al (Th-75) reported that 16,500 smears at \$2 apiece identified 56 cases. If we apply an inflation factor of 1.3, add \$5 per smear inconvenience cost, and assume that 17% of the detected cases resulted in lives saved (from the Mayo Clinic Study), the cost becomes [(1.3 x \$2) + \$5] x 16,500 = \$125,000 to save .17 x 56 = 9.5 lives, or \$13,000/life saved.

The Walton Report (Wa-76) on cervical cancer in Canada principally between 1961 and 1972 found that the mortality rate which was initially 20×10^{-5}/year among women 30-64 decreases roughly in proportion to the percentage of women screened. Thus a 50% screening of 100,000 women would save 10 lives, one life saved per 5000 screenings. If the inflation corrected cost of screening, plus the inconvenience cost is \$10 (as in the Mayo Clinic case), the cost per life saved is \$50,000. This is completely non-selective screening.





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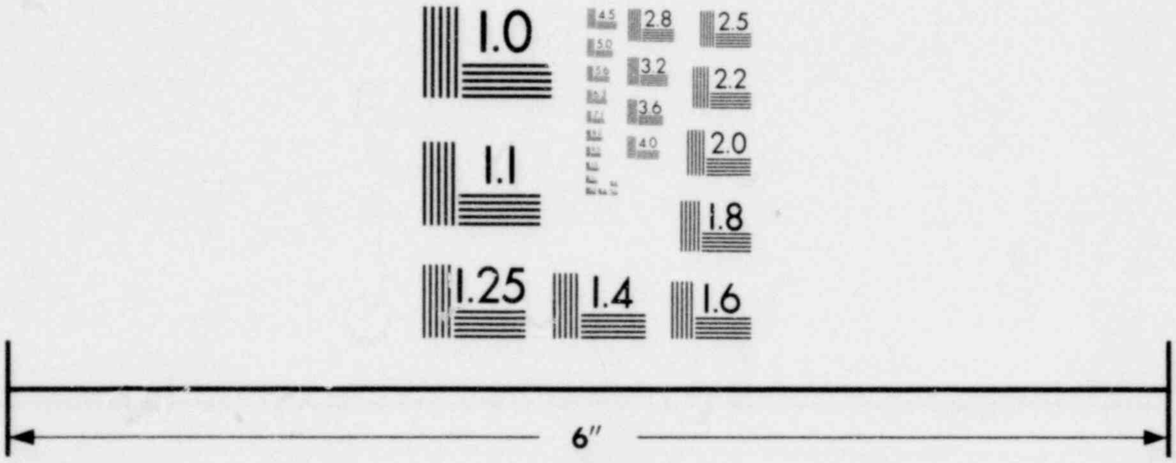

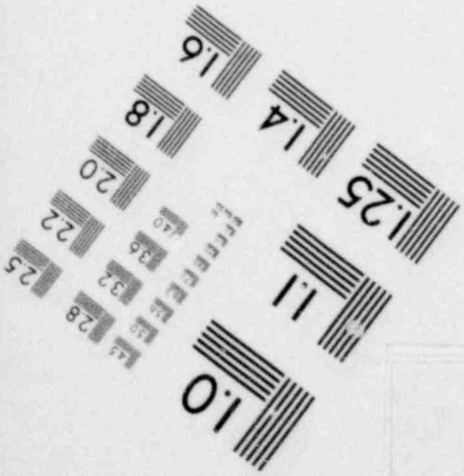

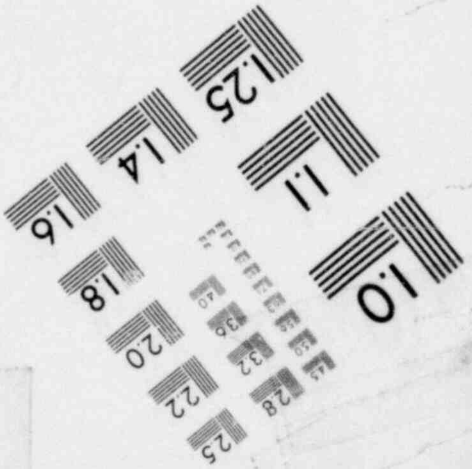

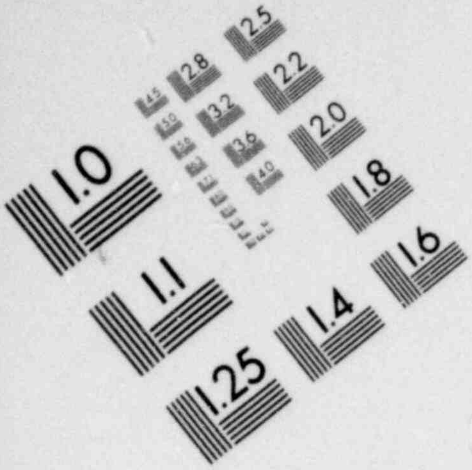

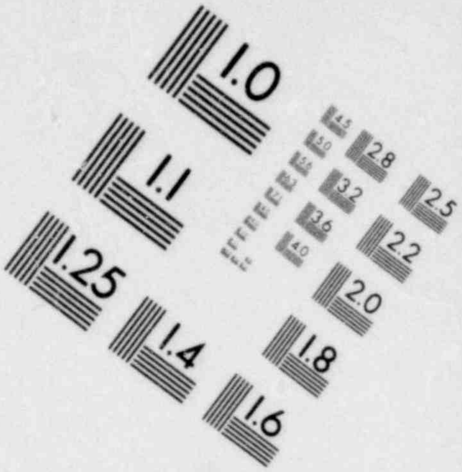

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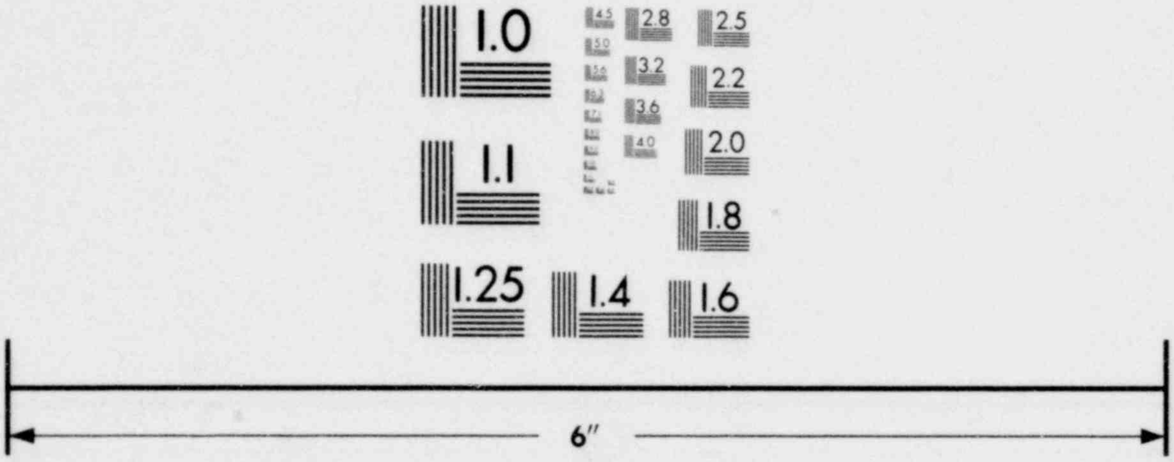

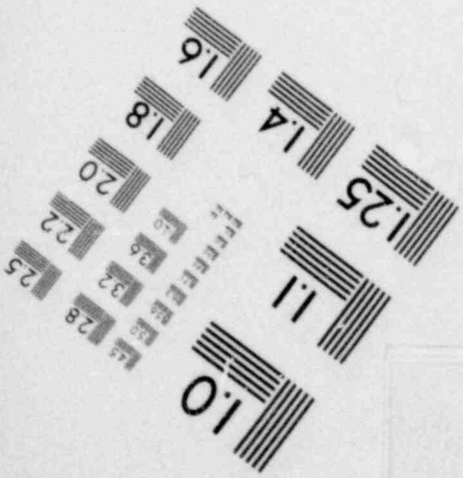

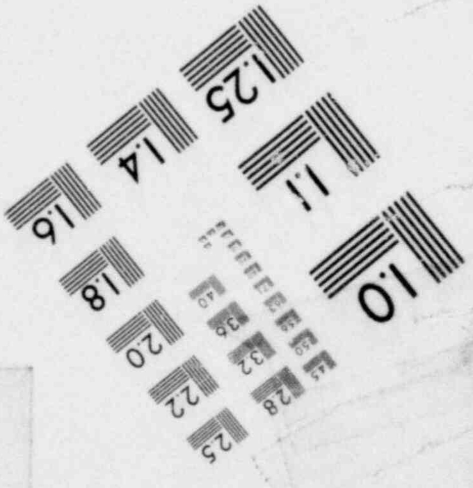

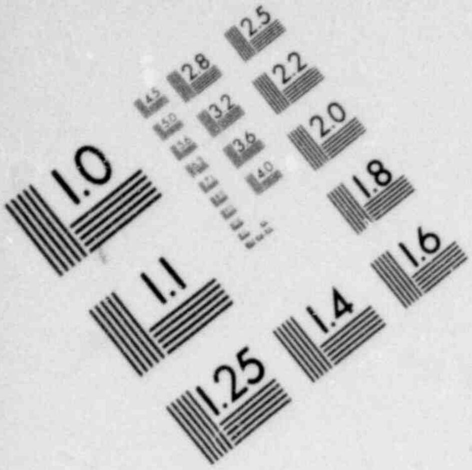

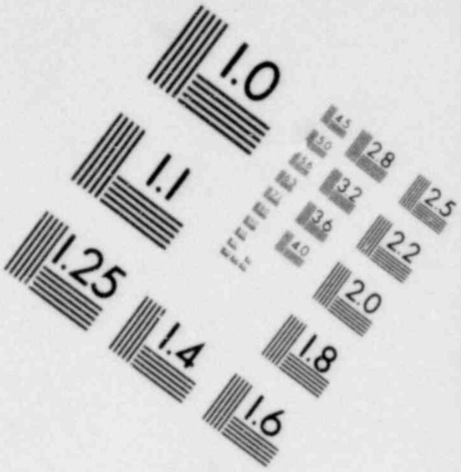

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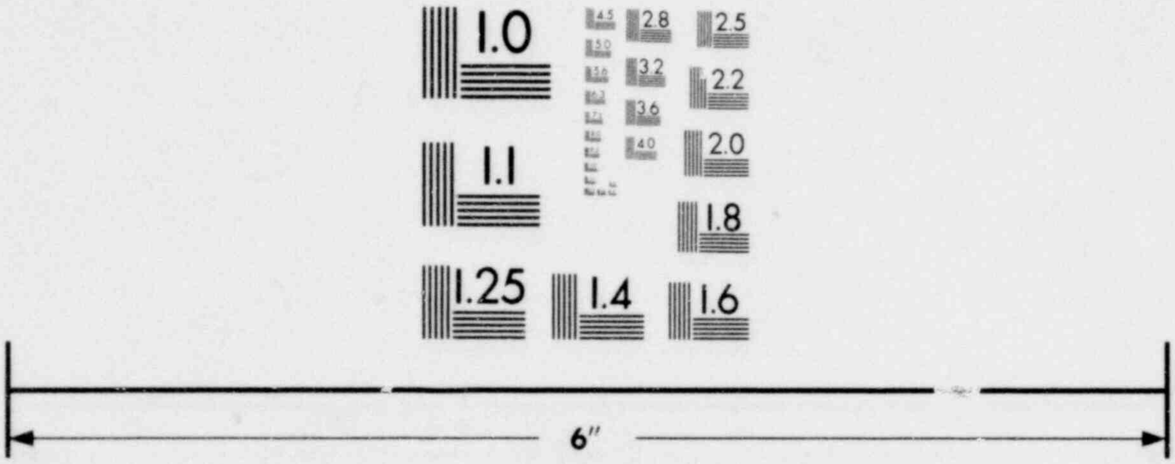

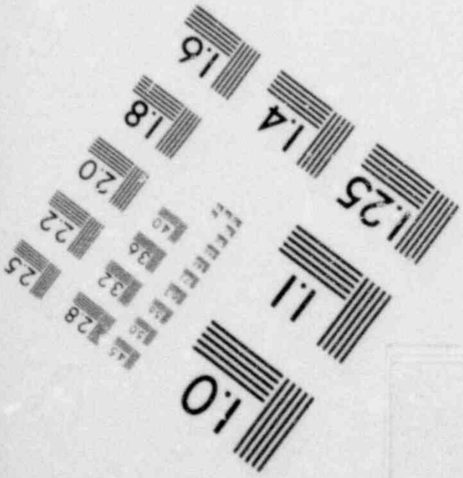

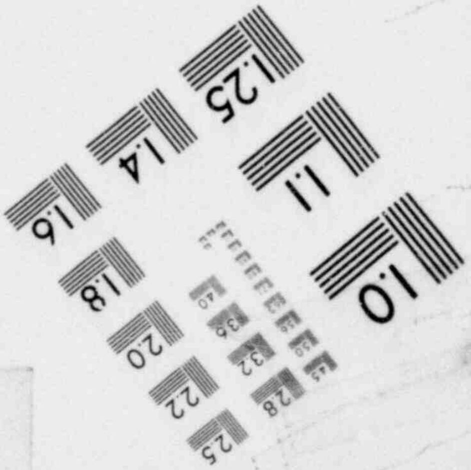

Grosse (Gr-72, JEC-69) estimated that a government program of screening 9.4×10^6 women at a cost of \$10.44 each would find 107,000 cases and avert death in 44,000 of these. With corrections for inflation and inconvenience, the cost approaches \$20 per examination, giving a cost/life saved of $(9.4 \times 10^6 \times 20)/44 \times 10^3 = \$4,300$.

Rhodes (Rh-78) gives a cost of \$3500/**life** saved without detail.

In view of the above, it seems conservative to estimate that cervical cancer screening programs can save one life for every \$25,000 spent. Since an average life saved corresponds to a gain of 40 years of life expectancy, the cost per 20 years of life expectancy gained is \$12,500.

2. Breast Cancer Screening

Breast cancer is the leading cause of cancer death among U.S. females, with an overall mortality rate of 23×10^{-5}/year, and several times higher for ages beyond 50. When detected early, it is frequently curable, and early detection is reasonably efficient with X-ray and clinical examination.

Shapiro et al (Sh-72) reported on a clinical trial in New York City involving 31,000 women aged 40-64 invited for screening of whom 20,000 responded, and 31,000 unscreened controls. In a five year period, there were 40 deaths from breast cancer among those invited vs 63 among the controls, which may be interpreted as saving 23 lives. The cost was \$40/examination, which with our inflation and inconvience factor becomes \$60, or 20,000 x \$60/23 = \$52,000/life saved. This price could have been substantially reduced by limiting the service to those above age 50.

Kristein (Kr-77) gives breast cancer incidence among females of age 55-64 as 2 x 10^{-3}, so among 1 million women there would be 2000 cases/year of whom 42% would normally die and 20% of these, 169 would be saved (this is half the save rate in Sh-72). He gives the cost as \$40/examination which remains approximately unchanged when corrected for inflation and inconvenience. The cost per life saved is then 40 x 10^6/169 = \$240,000. However, he estimates that the radiation from the X-rays would cause 67 deaths (this seems high for women of that age) which increases the cost/life saved to 40 x 10^6/102 = \$400,000. He considers this to be obviously cost ineffective.

Irwig (Ir-74) reports on British experience as \$3300/cancer detected with these cases having a 1/3 increase in 5-year survival over cases developing without screening. This represents about a 20% increase in 5-year survival, or perhaps a 12% increase in long-term survival. The cost/life saved is then \$3300/.12 = \$28,000. With inflation and inconvenience included this might be increased to \$40,000. Irwig calls this price "costly" and concludes "it would seem wise to await [improved] developments before considering the introduction of mass screening for breast cancer."

Grosse (Gr-72, JEC-69) estimates that a government screening program covering 2.3 x 10^6 women would cost \$7.79 per examination and eventually avert 2936 deaths. With inflation and inconvenience corrections, the cost becomes \$17 per examination, giving a cost/life saved = 17 x 2.3 x 10^6/2936 - \$13,300.

It is difficult to reconcile the wide variations we have found here, but the actual cost is not the important point for our purpose; we are interested in the cost as perceived by those in a position to institute screening programs. Since the Kristein analysis is rather recent, we must conclude that screening programs were not widely instituted when the perceived cost was in the range below $80,000/life saved. In a 1977 Gallup poll (Ga-77), 51% of women above age 18 said that they had had some type of breast examination during the previous year.

3. Lung Cancer Screening

Lung cancer is the largest cancer killer by far among U.S. males, with a rate approaching 50 x 10^{-5}/year among all males and several times higher than this for heavy cigarette smokers. Early detection is facilitated by X-ray and sputum cytology studies, and early detection is the key to survival, although even at best the chance of survival is small.

The most optimistic screening information comes from two studies in London (Na-68, Br-69) involving about 30,000 subjects each, plus an equal number of controls. They report costs as low as $350/cancer found and cured among heavy smokers, but Boucot and Weiss (Bo-73a) estimate that their costs for X-ray film alone should have been $12,500/survivor, and with inconvenience and other costs and a correction for inflation, the cost would be increased to perhaps $30,000/life saved.

Colley (Co-74) estimates the costs of the London projects as $1300 per case found and cured and concludes that the programs should be phased out! With our inflation and inconvenience factors, the cost would be raised to about $20,000/life saved.

Boucot and Weiss (Bo-73), working in Philadelphia, examined 10,000 men at six month intervals for three years, for a total cost of $250,000 and found and cured three lung cancers, a cost of $83,000/ life saved. They conclude "It is questionable whether the community could afford the price." With our inflation and inconvenience factors, the cost would be increased to about $200,000/life saved.

The Mayo Lung Project (Fo-75) detected 25 lung cancers (plus two cancers of the upper respiratory tract and one cancer of the tongue) in their first examinations of 3900 participants. Following pulmonary resections, the prognosis was good in 12 of these cases. If three of these prove to be cured, and the cost of an examination is taken to be $50 (including inconvenience), a single examination will have saved three lives at a cost of $195,000 or $65,000/life saved. This takes no credit for the three other cancers found and cured.

Actually, the Mayo project was designed to provide examinations at four month intervals in order to detect newly developing cancers which they estimate to be 50% curable. In the early work they found (Fo-75) six cases in 3000 follow-up examinations, which hopefully corresponds to one cure/1000 examinations or $50,000/life saved. Recent experience (Fo-78) has detected 4.5 cancers/yr-1000 people, which, with three examinations/ year at $50 each and a 50% cure rate correspond to 150/2.3 x 10^{-3} = $65,000 per life saved.

In view of the above, it seems reasonably conservative to conclude that, at least in the perception of those in a position to institute programs, lives could be saved by lung cancer screening at a cost of $70,000 each. The 1977 Gallup poll (Ga-77) indicated that 26% of adult men and women have lung X-rays each year.

4. Screening for Cancer of Colon and Rectum

Cancer of the colon and rectum causes an annual mortality rate in the U.S. of 20×10^{-5} for males and 15×10^{-5} for females; the rates are much higher for ages above 45. A simple screening technique involves fecal blood tests, and a more elaborate procedure is visual examination by proctosigmoidoscopy.

Kristein (Kr-77) gives the mortality rate for all people over 55 as 3×10^{-3}/year and estimates that 20% of these could be saved by early detection with fecal blood tests at a cost of $2 each. We add another $2 as an inconvenience cost as this requires only turning in a fecal sample with no office time. For a program involving 10^6 people, there would then be 3000 cases of which 600 would be saved at a cost of $\$4 \times 10^6$. The cost per life saved would then be $6,700.

Bolt (Bo-71) estimates that by screening 9000 people above age 45 by proctosigmoidoscopy, one can expect to find 20 colorectal cancers and cure 17 of them whereas only 10 of them would be cured without screening, a net saving of seven lives. He estimates the cost to be $12/scan, which gives a cost/life saved = $12 x 9000/7 = $16,000. He argues that this price is too high to be practical! With our corrections for inflation and inconvenience, the cost per life saved is raised to $27,000.

Gilbertson (Gi-74) estimates that screening of 400,000 people would detect 1300 cases of which 88% would survive vs 50% without this early detection, a saving of (.88-.50) x 1300 = 494 lives. He estimates the cost at $11.73/examination, but adding our inflation factor and inconvenience charge this becomes $20. The cost/life saved is then 20 x 400,000/494 = $16,000.

Grosse (Gr-72, JEC-69) estimates the cost of an examination at $20.10 which, corrected for inflation and the inconvenience becomes $35. He estimates one case found per 496 examinations, with an additional 22% cured as a result of the early detection. The cost per life saved is then $35 x 496/.22 = $79,000.

Since Grosse's work is rather old, we give it less weight and conclude that lives can be saved by proctosigmoidoscopy screening at a cost of $30,000 each, and a screening program in fecal blood tests could save lives at a cost of perhaps $10,000 each. According to the 1977 Gallup poll (Ga-77), only 8% of all men and 12% of those aged 50 and above had proctoscopic examinations in the previous year.

5. Miscellaneous Cancer Screening and Comments

Grosse (Gr-72, JEC-69) estimates that screening for cancers of the head and neck could save lives at a cost of $44,000 each. With corrections for inflation and inconvenience charge, this becomes $75,000.

Cannon Mills, a large textile manufacturing corporation runs a program of medical screening of its employees for colorectal (fecal blood), cervical, and breast cancer, blood pressure, and diabetes. The exams cost $8 for men and $12 for women, or an average of about $9, but it would seem that only about $7 of this should be charged to cancer screening. In 11,000 examinations, 23 cancers were found (He-77). If three additional cures are obtained as a result of this early detection, the cost would be 7 x 11,000/3 = $26,000. This item is entered as "multiple cancer screening" in Table 1.

The Lancet ran an extensive series on cancer screening, and in summary papers on the series, Randall (Ra-74) favored screening for cervical cancer but recommended caution on all others, while Holland (Ho-74a) concluded that no type of cancer screening is worth the cost!

6. Hypertension Screening and Control

Hypertension (high blood pressure) is a contributory factor in about one-third of all fatalities from heart disease and stroke. It is also a fairly common condition; in one large screening activity involving one million Americans, 25% had diastolic pressure above 90 and 12% were above 95 (St-76). In this study, 28% of these cases had been previously undetected, 11% had been detected but untreated, and 17% had been treated but uncontrolled, so fully 55% of the 25%, or 13% of those screened, obtained important information. Since blood pressure measurement is an extremely simple and cheap procedure, this suggests that the cost-benefit ratio would be very favorable, although it is not easy to quantify because hypertension is not ordinarily a direct cause of death. However, an analsyis by Kristein (Kr-77) indicates that such screening is cost effective even from the standpoint of money loss from missing work.

We derive an estimate of cost/life saved from finding and controlling blood pressure as follows (St-75): for males 55-64 years old, the annual mortality risk can be reduced from 219 x 10^{-4} to 179 x 10^{-4} by reducing diastolic blood pressure from 97 to 87 mm-Hg, a reduction of 40 x 10^{-4}/year, at a cost of \$150/year for medicine and care plus perhaps an equal amount for inconvenience. This corresponds to \$300/40 x 10^{-4} = \$75,000/life saved. Similarly male mortality rates in this age range can be reduced by 60 x 10^{-4} by reducing blood pressure from 102 to 87 mm-Hg, which costs about \$240/year for medicine and treatment plus a somewhat lesser amount for inconvenience, which corresponds to about \$450/60 x 10^{-4} = \$75,000/fatality averted. For females and males in adjacent age ranges, the reduced mortality is 3-5 times smaller so the cost per fatality averted would go up to \$300,000, but this does not change the above value for 55-64 years old males which is listed in Table 1.

It may be noted that we have not mentioned the costs of screening here; actually they are included but they contribute a rather small amount to the above costs.

7. Kidney Dialysis

About 6000 Americans need kidney dialysis treatment on a regular basis, but only 850 were receiving it in 1968 while the rest were condemned to early death. (Britain and Sweden were committed to provide treatement for all.) A person on dialysis has a life expectancy of about nine years ([illegible]1-68) and the cost is about \$10,000/year, whence the average cost to avert early death is about $90,000. A recent cost estimate (Rh-78) is $30,000/year which gives a cost per death averted of $270,000. In Table 1 we list an interpolated value for 1975 of about $200,000. If we standardize to 20 years of life expectancy, this is increased to $440,000.

It may be noted that the costs here are much higher than those of other medical items. This seems reasonable in view of the fact that the person at risk is readily identifiable in advance, and it is much more difficult to condemn a particular person to certain death than to condemn large numbers of people to a slightly increased risk. The kidney dialysis item is therefore less applicable to effects of radiation than are the other items.

8. Mobile Intensive Care Units

About one-third of all deaths in the United States are from heart attacks, and 30% of these are in people less than 65 years old. Two-thirds of the deaths occur before the patient reaches a hospital, so many lives could be saved by providing more prompt care.

Zeckhauser and Shepard (Ze-76) estimated that a mobile coronary care unit (MCCU) which involves an ambulance with a trained paramedic and coronary monitoring and defibrillation equipment could save a life in 8% of all heart attacks (reducing "dead on arrival" at hospitals from 22% to 14%) at a cost of $400/attack. This represents a cost of 400/.08 = $5000/life saved. Additional treatment at the hospital costs $3500 and follow up care costs $400/year for the eight years of remaining life expectancy, which adds up to $12,000/life saved.

Acton (Ac-73) estimated that for a community of 100,000 a special ambulance program would save 11 lives/year at a cost of $24,000 plus spill-over costs of about $68,000 for subsequent hospital care (including ruling out heart attack as the diagnosis in most cases) for a total of $92,000, or $8400/life saved. Alternatively, an MCCU could save 15 lives at a cost of $42,000 plus $78,000 in spill-over costs or $8000/life saved.

When the effectiveness of this type of service was recognized, programs were implemented in all large cities (Br-79, Ri-79). It was soon found that efficiency could be improved if the paramedic was trained and the ambulance was equipped for handling severe burns, trauma, and other injuries, and these units are now known as Mobile Intensive Care Units (MICU). In areas served by them, there is typically one unit for each 100,000 people, handling an average of about 10 calls per day. We assume that the costs are those from the above discussion, about $12,000 per life saved.

In order to determine an implicit valuation of a human life, one can observe how small a community does not have such a service. It is estimated (Ri-79) that the great majority of communities with more than 75,000 population either have, or are considering obtaining. this service. On the other extreme it is estimated that such a service would be highly unusual in a community of less than 25,000. We assume then that it is not generally considered cost effective in communities of less than 40,000, and we further assume that the cost per life saved is inversely proportional to the population serviced below 100,000. This yields a cost at which the service is only partially implemented to be \$12,000 x (100,000/40,000) = \$30,000 per life saved. This estimate is conservative in that it ignores benefits from servicing conditions other than heart attacks.

B. Traffic Safety Measures

Over 35,000 Americans die from accidents inside automobiles each year, so it seems reasonable to seek technological methods for protecting them. Congress passed the National Traffic and Motor Vehicle Safety Act of 1966, setting up a National Highway Traffic Safety Administration to attack the problem and since that time there has been a great deal of activity in this area. We review some of the cost-benefit information that has developed from it.

Most of the items to be discussed have benefits in averting injuries as well as deaths. For every traffic fatality there are 40 injuries (Na-75) resulting in disability extending beyond the day of the accident and many of them have life-long serious effects. As a general average it would probably be reasonable to assign only half of the costs to averting fatalities. Since we do not do this, there is approximately a factor of two conservatism in all figures. Traffic fatalities differ from most medical problems in preferentially affecting the younger segment of the population, so about 40 years of life expectancy are lost in an average traffic fatality. This is reflected in the right hand column of Table 1.

Many of the measures taken require an appreciable effort by the people protected so the dollar cost is not the entire cost. For example, seat belts are tremendously cost effective, but are generally not used because of the effort involved. Rather than trying to assign dollar values to this effort, we will ignore measures of this type and confine our attention to passive measures.

1. Auto safety improvements, 1966-70.

According to an analyses by the General Accounting Office (Ge-76), the effects up through 1974 of safety improvements introduced in 1966-70 model cars were: amortized costs - $3 billion, lives saved - 28,200. This gives a cost/life saved = $106,000. Corrected for inflation increases this to $130,000. The GAO Report found little benefit up to 1974 from items introduced in 1971-74 models. Their amortized cost was $205 million; if this is included the above number is raised to $140,000.

One item introduced during this period was the energy absorbing steering column. It is estimated (Ge-76) that it cost $153 million and would avoid 1800 fatalities (plus an equal number of injuries). This corresponds to $83,000 per life saved; corrected for inflation it becomes $100,000.

2. Air bags

Air bags are an especially clean example of Society's evaluation of human life since they save lives and cost nothing but money, but they are not being used because of their cost (there have been allegations that they do not function as expected, but these have been proven to be false (In-76).

According to Allstate Insurance Company, an air bag reduces a driver's mortality risk from 2.7×10^{-8} to 1.3×10^{-8} per mile (Ka-76). The cost of an air bag as an option was $315 in 1976, although this would be greatly reduced to perhaps $100 if it were standard equipment (Ka-76). We take the cost to be $200 and assume that it gives protection at this cost for 50,000 miles. The cost/life saved is then $200/1.4 \times 10^{-8} \times 50{,}000 = \$290{,}000$.

Patrick (Pa-75) estimates that equipping essentially all automobiles with airbags to protect the driver over a ten year period would cost $18.5 billion and would save 46,400 lives. This corresponds to $400,000 per life saved.

Stork (St-73) estimates that using four air bags in a car would cost $77/year, and that if all cars were equipped, fatalities would be cut in half. This corresponds to a cost of $\$77 \times 10^{8}$ to equip all U.S. automobiles and it would save 17,000 lives, a cost/life saved of $450,000. Protecting four passengers is only about half as cost-effective as protecting the driver (the average car carries 1.5 people); with a correction for inflation, this gives $250,000/life saved by protecting the driver only.

Averaging our three estimates gives $320,000 per life saved.

3. Automobile tire inspection

Most states have inspection requirements on automobile tires, and in many places it is illegal to drive on worn tires. The rationale for this is that worn tires have a better chance of a blow-out which can cause an accident.

About 4% of all fatal traffic accidents in the U.S. are caused by blow-outs, which amounts to 1800 fatalities per year. Roughly we assume that this number would be doubled without the inspection and legal requirements. There are 180 million passenger car tires sold each year in the U.S., and we crudely estimate that 30 million of these would not be purchased without the above requirements. If an average tire costs \$25, this is $\$25 \times 30 \times 10^6/1800 = \$400,000$ per life saved. It is evident from the quality of these inputs that this estimate is particularly crude.

It is interesting here to consider the costs some people are willing to pay to protect their own lives and those of their loved ones by buying tires that will not blow-out. These cost at least \$30 additional, so if all automobiles were so equipped this would represent a cost of $\$30 \times 180 \times 10^6/1800 = \$3$ million per life saved.

4. Use of small cars vs standard size

The risk of being killed while riding in a small car is about 25% higher per mile of travel than in a standard size car (Co-76). The average American's risk of being killed in an automobile is 1.6×10^{-4}/year, whence use of the heavier car averts a risk of 4×10^{-5} per year. The added cost of a heavier car, including operating and maintenance costs, is perhaps \$500/year. Since an average car carries two people, the cost per fatality averted is then $\$500/2 \times 4 \times 10^{-5} = \$6$ million. Of course this applies only if added safety is the sole reason for purchase of the larger car. This item is not included in Table 1 because Society has made no move to ban the use of small cars.

5. Miscellaneous auto safety devices and comments

Stork (St-73) estimates that in West Germany, a fleet of 50 rescue helicopters could save 400 lives per year at a cost of $24.4 million which, with a small correction for inflation, is $65,000/life saved. He also estimates that a fleet of 150 rescue cars in urban areas could save 350 lives/year at a cost of $73.5 million, which, with an inflation correction, is $230,000/life saved. The helicopters are the more cost-effective option so only it is included in Table 1.

Patrick (Pa-75) estimates that a $135 passive 3-point harness, a seat belt-shoulder harness that closes over the driver without his intervention, would avert 30% of all fatalities. Equipping all U.S. cars over a 10 year period would cost $13.5 billion and save 55,000 lives, a cost of $250,000/life saved.

He similarly estimates that a passive torso belt - knee bar restraint combination would cost $5 billion and would save 46,000 lives, a cost of $110,000/life saved.

From the entries on auto safety in Table 1, it is apparent that many lives can be saved at costs in the $300,000 range or less. However, the auto safety program has all but ground to a halt (In-76a); in 1970-73, 16 new standards were issued, but only one new standards was issued in 1974-75.

6. Driver education

Kaywood (Ka-76) has estimated that a high school course in Driver Education for all students would reduce traffic fatalities by 10-15%. It would therefore presumably save about 5800 lives per year. Such courses involve time and effort expenditure by the students, so a dollar cost must include compensation for these. A brief opinion survey indicated that a payment of $50 would be ample inducement for the great majority of students. Instruction costs average about $75 per student (Na-78), but there are probably hidden costs (e.g. automobiles are often donated) to bring the total cost to $150/student. For 3.5 $\times 10^6$ students/year, the cost/life saved is $150 $\times$ 3.5 $\times 10^6$/5800 = $90,000.

Driver education courses are now taken by 81% of all high school students (Na-78), so it is perhaps unfair to include this option as not fully implemented. However, 20% of all high schools, including many large ones, do not offer courses, and there have been many recent indications that programs are being cut back (Ka-76a).

7. Highway construction improvements

There are many practices in highway construction and operation that could be improved to save lives at a cost of money alone. For example, it is estimated (Ta-76) that moving light posts 30 feet back from the edge of highways would save 500 lives per year. About 6000 people per year are killed in collisions with guardrails, and there are guardrail construction techniques that could save most of them. A recent paper (Sp-77) stated that there are many local highway improvements that could be implemented in Oklahoma that would save a life for every $43,000 spent.

The National Highway Safety Needs Report (US-76) conducted a study by polling knowledgeable people to determine the cost per fatality forestalled of various measures. The most cost effective measures which involve no personal effort or inconvenience are listed in Table 1 and explained below:

Highway construction and maintenance practices refer to following the Manual on Uniform Traffic Control Devices including inspection and maintenance; this would save 46 lives/year at a cost of $20,000/life. Regulatory and Warning Signs refers to upgrading and installation of signs in accordance with the afore-mentioned Manual; this would save 367 lives/year at a cost of $34,000 each. Guardrail includes using improved designs in a program to replace substandard and damaged units; this would save 316 lives/year at a similar cost. Skid resistance refers to locating places where slippery conditions are contributing to highway accidents and implementing construction techniques to improve their skid resistance; this would save 374 lives/year at a cost of $42,200/life saved. Bridge rails and parapets includes design and installation of these so as to redirect vehicles which would otherwise have collisions with objects or other vehicles; this would save 152 lives/year at a cost of $46,000 per fatality averted. Wrong-way entry avoidance involves use of standard techniques to avoid wrong-way entrance onto freeways; this would save 78 lives/year at a cost of $49,400 each. Impact abosrbing devices means using these at critical roadside points where removal of fixed object hazards and yield-on-impact techniques are not feasible; this would save 678 lives/year at a cost of $108,000 per life saved. Breakaway sign and lighting supports involves using these rather than rigid supports along high speed highways, with a program for systematic replacement; this would save 325 lives/year at a cost of $116,000 each. Median barriers includes use of improved design on these to reduce consequences of collisions, and includes programs for replacing substandard and damaged sections; this would save 53 lives/year at a cost of $228,000 each. Clear roadside recovery areas includes areas that enable vehicles which leave the travel lanes to return without injury; this includes construction of gradual side slopes and removal of hazardous drainage features, trees, and rocks for a minimum of 30 feet from the edge of freeways. This would save 53 lives/year and would cost $284,000 per fatality overted.

If these numbers are credible, there are many ways that lives can be saved for less than $50,000 spent on highway improvements, and this general category has one of the most favorable cost-benefit ratios. However, there has been strong criticism that the program is floundering (Ge-76a).

C. Miscellaneous Categories

1. Food for overseas relief

Starvation is a common experience in many under-developed nations of the world and its effects are especially important in children. About

60 million children are born each year in these countries, and 25-30% of them will die before reaching age five from malnutrition and related disease, a total of 15-18 million deaths/year that could be averted by food relief. Moreover, those that survive the first five years suffer throughout life from the effects of this early starvation.

Ward (Wa-74) has estimated that most of these children could be saved by $20/year worth of food, but most estimates are higher. One estimate (Eg-77) is that $120/year would do the job in Brazil. In the Rice Bowl of Asia, $10/year would supply the needed milk and $50/year would provide the needed extra protein for adequate nutrition.

To derive an estimate, we conservatively assume that $150 per year through the first five years of life would avert half of the deaths. This corresponds to a $750 expenditure per child to increase the probability of survival by 14%, or $5300/life saved. This is probably an over-estimate for saving the young children, but it may be compensated by the need for some additional food for older children.

2. Air pollution control

Typical esitmates are that sulfur dioxide (SO_2) air pollution causes about 10,000 fatalities/year in the United States (Co-76). About half of the SO_2 comes from coal burning power plants, and it is hoped that 85% of this contribution can be eliminated by installation of scrubbers, at least on newly constructed plants. This would save 4300 lives per year.

Our current coal-generated electricity could be produced by about 150 of these plants. According to EPA estimates (Sc-78) the cost of SO_2 scrubbers is 0.3 cents/KW-hr which works out to be \$15 million per year for each plant. This therefore represents an expenditure of \$2.3 x 10^9 to save 4300 lives, or \$500,000/life saved.

3. Smoke alarms in homes

It is estimated (Ru-78) that smoke alarms in homes would save 8,000 lives/year. We estimate that such protection could be supplied by the production and distribution of 10 million units/year at a cost, including installation, maintenance over a 10 year average lifetime, and inconvenience, of about \$50 each. This corresponds to a cost per life saved of 50 x 10^7/ 8 x 10^3 = \$60,000.

There are currently 10 million smoke alarms in use in the United States (Gr-79) which means that something less than 15% of all homes are protected.

4. Higher pay for risky jobs

Thaler and Rosen (Th-75a) carried out a correlation analysis of salaries vs risk in various jobs, and concluded that the higher pay for an .001 increase in mortality risk is \$260/year. This corresponds to an evaluation of a life at \$260,000.

Carlson (Ca-63) calculated that the flight pay for a U.S. Air Force Captain implies an evaluation of his life at between \$135,000 and

$980,000, depending on the type of plane flown. If we take the mean of these and apply an inflation factor, the result is about $600,000.

5. Industrial safety

A study of the effects of the Coal Mine Health and Safety Act of 1969 (De-78) indicated that compliance requires the addition of 118,000 miners in U.S. coal mines. The average salary of a coal miner is $14,000/year (Co-77), and we assume an additional 50% for overhead and fringe benefits, which brings the total annual cost to $\$14,000 \times 1.5 \times 118,000 = \$2.5 \times 10^9$. The new safety measures have reduced the annual average fatality toll in coal mines from 260 in 1965-70 to 145 in 1972-75 (Co-77), a saving of 115 lives/year. The cost per life saved is then $\$2.5 \times 10^9/115 = \$22$ million.

A similar study of the effects of the Federal Metal and Non-metal Mine Safety Act of 1966 indicated (De-78) that compliance requires employment of 42,000 additional miners at $12,000/year (Co-77), which, if we assume 50% overhead, amounts to $750 million/year. This has reduced accident fataility rates (Co-77) by no more than 22 per year (93/year in 1965-70 vs 71/year in 1973-75, but 152 in 1972), which corresponds to $34 million per life saved.

Rhodes (Rh-78) reports that occupational safety standards for coke fumes corresponds to expenditure of $4.5 million/life saved. He questions the wisdom of this practice, but says that it is strongly supported by the Union.

6. Aircraft

Carlson (Ca-63) estimated that the cost of the ejection system on a B-58 bomber implies a value of life somewhere between \$1.7 million and \$9 million. If we take an average of these and apply a correction for inflation, we get a cost of \$8 million/life saved.

Carlson also estimates that the emergency procedures for pilots flying jet fighter planes imply a value of his life (for recommending ejection) in excess of \$270,000. With an inflation correction this becomes \$450,000. In Table 1, we list the mean proportion between the costs for bomber and fighter pilots at \$2 million.

Morlat (Mo-70) estimated that in France about \$900,000/life saved is spent on additional civilian aircraft safety measures. Corrected for inflation this becomes \$1.2 million.

D. Radiation-related Activities

The field of radiation protection involves a great many health protection regulations and standards, and in many situations these can be translated into a value placed on fatalities averted. In this section we make this translation for several cases. In general, radiation induced cancers reduce life expectancy by about 20 years, so the listings in the two columns of Table 1 are identical.

1. Radium in drinking water

The Environmental Protection Agency requires that the radium content in drinking water be no larger than 5pCi/liter and that remedial action be taken where necessary to meet this standard (EP-76). They estimate that compliance with this standard will require expenditure of $2.5 million per fataility averted.

2. Medical X-rays

A 1970 Study by the U.S. Public Health Service (Ro-71) indicates that unnecessary exposures in medical X-rays can be substantially reduced at a cost averaging $1000 per machine by attaching more sophisticated collimation devices. Terrill (Te-72) estimated that this would reduce gonad exposures by 330 man-rem/year for each machine. If we assume that this advantage is maintained for six years, this represents an exposure reduction of 2000 man-rem for $1000, or 50¢/man-rem.

According to the BEIR Report (NA-72), one man-rem of exposure to the whole body induces 1.8×10^{-4} fatal cancers. If we make the reasonable assumption that on an average, gonadal and whole body doses are equal, improving X-ray machines can save lives at a cost of $0.5/1.8 \times 10^{-4} = \$2800$ each, or after a correction for inflation, for $3600/life saved.

3. ICRP Recommendations

The International Commission on Radiological Protection (IC-73) recommends values for cost/man-rem in the range $10-$250 to be used in cost-benefit analysis. The mean proportion of these is \$50/man-rem, which, with the BEIR risk estimator of 1.8×10^{-4}/man-rem, corresponds to a cost per life saved of \$280,000. With a correction for inflation this becomes \$320,000/fatality averted.

4. OMB Guidelines

The Office of Management and Budget, in OMB Circular A-94 (1972) recommends a value of \$1000/man-rem averted to be used as the justificable costs in analysis of reactor safety systems. With the 1.8×10^{-4} deaths/man-rem estimator and a correction for inflation, this corresponds to \$7 million per fatality averted.

5. Nuclear industry rad waste practice

In seeking guidance for application of the ALARA principle, the Nuclear Regulatory Commission imposed interim standards (10 CFR 50, Appendix I) of \$1000/man-rem to the whole body and to the thyroid as the incremental cost that must be spent for equipment to avert an incremental population dose. It was found that equipment already in place at all reactors easily conformed to these standards, and therefore this was made permanent in Regulatory Guides 1.109-1.113 (1976).

The fact that industry practice was already conforming to these standards implies that the money being spent for radwaste equipment exceeds \$1000/man-rem. For whole body radiation this implies expenditures of more than $\$1000/1.8 \times 10^{-4} = \$5.5$ million per fatality averted. If this is easily exceeded in all plants it is safe to conclude that the average expenditures are at least $10 million/fatality averted.

The mortality risk from thyroid exposure is very much lower than from whole body exposure. The UNSCEAR Report (Un-77) estimates 5 - 15 x 10^{-6}/rem. If we take 10 x 10^{-6}/rem, the expenditures for I^{131} emission control must be in excess of $1000/10 x 10^{-6} = $100 million per fatality averted.

6. Defense high level waste

The U.S. Department of Energy is proposing a $2.7 billion program to convert high level radioactive waste from the Savannah River Plant to a glass and store it in a deep geologic repository (Oe-78). One alternative plan is to leave the waste in its present liquid form and set up a trust fund to maintain it. at a cost of $500 million. It is estimated (En-77) that this would cause an additional 500 man-rem of radiation exposure. The more elaborate program therefore represents an additional expenditure of $2.2 x 10^9/500 = $4.4 x 10^6/man-rem averted. Dividing this by 1.8 x 10^{-4} fatalities/man-rem gives $25 billion/fatality averted.

To some extent the decision not to maintain the present system is based on the fact that it relies on future generations maintaining responsibility, although the costs for this are provided. An alternative plan which does not depend on such reliance would be to simply pump the unprocessed waste as a slurry into local bedrock. This involves an integrated exposure of 61,000 man-rem above the option chosen, and would cost $500 million. Thus the option chosen represents a straight trade-off of $2.2 x 10^9$ for 61,000 man-rem, or $36,000/man-rem which corresponds to $200 million/life saved. This is the number entered in Table 1. Similar projects are planned for the Hanford and Idaho Falls Waste.

7. Civilian high level radioactive waste

It is estimated (Co-79) that dumping high level radioactive waste in the ocean will eventually cause 0.17 eventual fatality/GWe-year without doing harm to ocean life, but this is considered too dangerous. The present plans are to spend about $3 million/GWe-yr for geologic disposal as a safer option. This represents a cost of $3 x 10^6/.17 = $18 million per fatality averted.

It should be noted here that the fatalities being averted are several thousand years in the future, which introduces the question of the relative value of averting a fatality now and in the distant future. This will be discussed in the next section.

Time Delay Considerations

It is conventional in cost-benefit analyses to discount money that will be spent or needed in the future at rates varying between 5% and 10% per year. For example if 5% discounting is used in the estimates of the economic value of a life from the standpoint of earnings (discussed in the Introduction), $10,000 earned 20 years from now is counted as having a present value of $5000. This discounting is in addition to inflation.

Considerations of this type have a tremendous importance when considering the cost effectiveness of managing radioactive waste which may cause fatalities far in the future. One dollar now at even 1% annual real interest (i.e. discounting inflation) becomes $20,000 after 1000 years, $400 million after 2000 years, $8 trillion after 3000 years, etc. At 5% or 10% interest the time before these values are reached is reduced by a factor of 5 or 10. Based on this reasoning it is completely cost ineffective to spend any money now to save lives a thousand or perhaps even a few hundred years in the future. It would be far better for those living then if we would instead set up a modest trust fund which will give them copious supplies of money to save lives by methods whose value they will be in a better position to judge than we are now. For example, a simple cure may be found for cancer, or it may be determined that low level radiation is harmless, in either of which case our money would be wasted.

This line of reasoning would not be applicable if our actions now could cause large scale killing in the distant future, but this is clearly not the case. It would be extremely difficult to construct a credible scenario in which a release of deeply buried radioactive waste could cause a detectable number of excess cancers at any future date.

Perhaps the concept of a trust fund extending over many hundreds of years is unrealistic since it assumes that capital will continue to attract real interest, or that capital can be invested to generate more wealth than its original value. But there are more subtle ways in which we can invest money for the benefit of our progeny even more effectively. For example, money invested in research now benefits all future generations, paying a high rate of compound interest if we can judge by past performance. The high standard of living we enjoy today is largely the product of small amounts of money and effort invested in research over the past two centuries.

Another way of arriving at a similar conclusion is to recognize that our attempts to spend money now to save lives in the distant future represents what some consider our moral obligation to leave each segment of the environment to our progeny in at least as good a condition as we found it. This is an intuitively appealing goal, but it is wholly unrealistic. Anything we can do in this regard is completely overshadowed by the horrible legacy we leave our progeny when we consume all of the earth's rich mineral resources, What we can do is make enough positive contributions to turn the world over to our progeny in better over-all condition than we found it. It seems obvious that with this goal in mind, it would be better to spend money on research than to spend millions of dollars to save the life of some person living in the distant future.

But since this paper deals with Society's valuations, we must point out that Society does not value future lives equivalently with lives of those now living. For example, with such a philosophy we would spend nearly all our money on medical research rather than on medical care. According to Table 1 we can save a life now for every $50,000 or so that we spend on medical care, and let us say that with medical research we can save one life/year for every $5 million dollars spent; if our concerns extend to 1000 years, we save 10 times as many lives with the research. It is obvious that this argument does not depend on the particulars of the costs we assume - with any assumed costs we will eventually save more lives with medical research than with medical care expenditures. But our Society does not behave that way - we spend far more money on medical care, and even our research expenditures are targeted at short term pay-offs. Congress was willing to spend vast sums on cancer research when it believed that it would develop a cure for cancer in our lifetime. If it were informed that the cure would not come for 500 years, the money would all but dry up instantly, although the number of lives that would be saved over the next several thousand years would be essentially the same.

If we accept the idea that the value of lives saved far in the future should be discounted at 1%/year, the final entry of Table 1 represents a rough estimate of the cost/life saved by not dumping nuclear waste in the oceans.

Polling

Another approach to determining public attitudes toward the value of saving a life is by polling samples of the public on questions whose answers depend only on that evaluation. Acton (Ac-73) used this approach to determine how much people were willing to spend for service by a mobile coronary care unit, and depending on how the question was phrased the equivalent valuation of a life was \$28,000 or \$43,000. This is in reasonable agreement with the value in Table 1.

We presented the same set of questions to classes of about 100 students in a course on Energy and Environment at University of Pittsburgh in two successive years, and essentially the same average results were obtained. We present a few examples, all of which the class was told are realistic:

1. If control equipment could be added in a nearby nuclear power plant to reduce your mortality risk from one in a million to one in 2 million, how much extra would you be willing to pay for electricity in order to add them? The average answer was \$25 which gives an evaluation of their life at $\$25/5 \times 10^{-7} = \$50$ million.
2. If control equipment could be added in a nearby coal-fired power plant to reduce your mortality risk from one in a thousand to one in 2000, how much extra would you be willing to pay for electricity in order to add them? The average answer was \$60, which gives an evaluation of their life at $\$60/5 \times 10^{-4} = \$120{,}000$.

3. How much money would you be willing to have the government spend on a health program that would save 1000 lives? The average answer was \$2.5 billion, which corresponds to \$2.5 million per life saved.
4. If having an air bag in your car does no harm other than adding to the cost, and if it reduces your mortality risk from one in 1500 to one in 3000, how much would you be willing to pay for the air bag? The average answer was \$170 which corresponds to \$110/(1/3000) = \$500,000 value for their life.
5. (For cigarette smokers only). If a new type cigarette came out that was in every way the same as your present brand except that it was guaranteed to avoid bad health effects, how much extra would you be willing to pay for it? The average answer was 50¢/pack. A one pack/day smoker buys 20,000 packs in a lifetime, so at 50¢/pack he pays \$10,000. A man loses 6.5 years of life expectancy and a woman loses 2.6 years from this habit (Co-79a), and since boys were a majority the average is 5 years. If we assume that an average early death involves 20 years loss of life expectancy, a one pack/day smoker has one chance in four of being such a victim. This gives a valuation of life at \$10,000/(1/4) = \$40,000.
6. If you were going on a 500 mile trip and had your choice between a bus and an automobile, and if all aspects of the two choices

were equal except for the added safety of the bus, how much extra would you be willing to pay to go by bus. Many answers were zero, but the average was $13. The risk is about 1×10^{-8}/mile (for thruway travel) $\times 500 = 5 \times 10^{-6}$, so the valuation implicit is $\$13/5 \times 10^{-6} = \$2.6$ million.

It is clear from the discrepancies in value of life implied by the various answers that these values are not calculated even subconsciously, at least by an average university student. This seems especially clear from #1 and #2 where the wording was almost identical and the numerical probabilities were given explicitly. The best interpretation we could devise is that a few tens of dollars sounds like a reasonable amount to spend for a risk reduction or a little less on a single day trip, $170 is a reasonable extra cost when buying a car, 50¢ extra seems reasonable for a pack of cigarettes, and a few billion dollars is about right for a government program; in each case, the expenditure is enough to be meaningful, but not enough to make a big difference.

Discussion

The wide variations in the values in Table 1 would seem to be worthy of extensive discussion. Some of them can be justified. The low value on food for overseas relief represents a common human attitude that charity begins at home, and the high expenditures for protecting miners and coke workers may be justifiable as the price they demand of us for their services (although they should perhaps be offered the alternative of having some of the costs now spent in protecting them added to their wages instead).

But aside from these few cases, it seems difficult to justify the differences morally. Indeed, one could argue that it is highly immoral for $100 million in funds obtained from the general citizenry to be spent in saving one life from ^{131}I emissions when that same money could save 2000 lives if it were spent on medical or traffic safety programs which are being held back for lack of money.

Sociologists and economists usually try to explain rather than to justify discrepancies like those in Table 1 (Fi-76, Li-78a, Sl-78). Human fears are not necessarily correlated with actual dangers, and government agencies are more concerned with allaying fears then with averting dangers. This could be interpreted as a cynical disregard for human welfare, but on the other hand it could be viewed as participatory democracy functioning properly by being responsive to the desires of the citizenry. In any case, it explains the large values in Table 1 for radiation related activities — with the exception of medical X-rays which the public does not view as radiation, and the ICRP recommendations which are not made (or used) by government agencies. The only solution to this dilemma would seem to be education, and it is clear from Table 1 that the radiation protection community has done a particularly poor job of educating the public.

Table 1. Value per fatality averted (1975 dollars) implied by various Societal activities (left column) and cost per 20 years of added life expectancy (right column).

Item	$ per fatality averted	$/20 yr life expectancy
Medical screening and care		
cervical cancer	$25,000	$13,000
breast cancer	80,000	60,000
lung cancer	70,000	70,000
colorectal cancer:		
fecal blood tests	10,000	10,000
proctoscopy	30,000	30,000
multiple screening	26,000	20,000
hypertension control	75,000	75,000
kidney dialysis	200,000	440,000
mobile intensive care units	30,000	75,000
Traffic safety		
auto safety equipment – 1966-70	130,000	65,000
steering column improvement	100,000	50,000
air bags (driver only)	320,000	160,000
tire inspection	400,000	200,000
rescue helicopters	65,000	33,000
passive 3-point harness	250,000	125,000
passive torso belt-knee bar	110,000	55,000
driver education	90,000	45,000
highway construc.-maint. practice	20,000	10,000
regulatory and warning signs	34,000	17,000
guardrail improvements	34,000	17,000
skid resistance	42,000	21,000
bridge rails and parapets	46,000	23,000
wrong way entry avoidance	50,000	25,000
impact absorbing roadside dev.	108,000	54,000
breakaway sign, lighting posts	116,000	58,000
median barrier improvement	228,000	114,000
clear roadside recovery area	284,000	142,000
Miscellaneous non-radiation		
food for overseas relief	5,300	2,500
sulfur scrubbers in power plants	500,000	1,500,000
smoke alarms in homes	60,000	40,000
higher pay for risky jobs	260,000	150,000
coal mine safety	22,000,000	13,000,000
other mine safety	34,000,000	20,000,000
coke fume standards	4,500,000	2,500,000
Air Force pilot safety	2,000,000	1,000,000
civilian aircraft (France)	1,200,000	600,000

Table 1 (cont'd)

Item	$ per fatality averted	$/20 yr life expectancy
Radiation related activities		
radium in drinking water	2,500,000	2,500,000
medical X-ray equipment	3,600	3,600
ICRP recommendations	320,000	320,000
OMB guidelines	7,000,000	7,000,000
radwaste practice-general	10,000,000	10,000,000
radwaste practice - ^{131}I	100,000,000	100,000,000
defense high level waste	200,000,000	200,000,000
civilian high level waste		
no discounting	18,000,000	18,000,000
discounting (1%/year)	~1,000,000,000	~1,000,000,000

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Vol. II

PART III
SPECIFIC COMMENTS BY THE AMERICAN MINING CONGRESS ON THE DRAFT GENERIC ENVIRONMENTAL IMPACT STATEMENT (GEIS) ON URANIUM MILLING (NUREG - 0511) AND ON THE PROPOSED REGULATIONS ON CRITERIA RELATING TO URANIUM MILL TAILINGS AND CONSTRUCTION OF MAJOR PLANTS (44 FED. REG. 50015, et seq.)

FOUNDED 1897

Submitted on October 24, 1979

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VOLUME II

PART III

SPECIFIC COMMENTS BY
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(NUREG-0511)

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(44 FED. REG. 50015, *et seq.*)

Prepared by the AMC Uranium Environmental Subcommittee

Submitted on October 24, 1979

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D'APPOLONIA

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FOR THE AMERICAN MINING CONGRESS
ON THE GENERIC ENVIRONMENTAL IMPACT STATEMENT
URANIUM MILLING
APRIL, 1979
U.S. NUCLEAR REGULATORY COMMISSION

INTRODUCTION

In Chapter 12 of the Generic Environmental Impact Statement on Uranium Milling (GEIS) recommendations are made concerning proposed regulatory actions for uranium mill tailings disposal. Under Item No. 6, the statement is made:

> "Steps should be taken to reduce seepage of toxic materials into the groundwater to the maximum extent reasonably achieveable. This could be accomplished by lining the bottom of the tailings area and reducing the inventory of the liquid impoundment by such means as dewatering tailings and recycling water from the tailings impoundments to the mill. Furthermore steps should be taken during stockpiling of ore to minimize penetration of radionuclides in the underlying soils; suitable methods include lining and/or compaction of ore storage areas."
> "The specific method, or combination of methods to be used must be worked out on the site-specific basis. While the primary method of protecting groundwater should be by isolation of tailings and tailings solutions, disposal involving contact with the groundwater will be considered by the staff provided supporting tests and analysis are presented demonstrating that the proposed disposal and treatment methods will preserve quality of groundwater."*

The data presented in the GEIS do not support the contention that isolation of tailings and tailings solutions should be the primary method of tailings disposal. Rather, the emphasis should be placed on utilizing the site-specific characteristics of the disposal area in an effort to select the best tailings management system for groundwater protection.

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*This is also Criteria 5 as set forth in the Proposal and Final Regulations on Uranium Mill Tailings Licensing and Criteria as published in the Federal Register on August 24, 1979.

The isolation of tailings and tailings solution may be the most appropriate management system for groundwater protection at one site yet not be the most advantageous system for accomplishing this goal at another site. The hydrologic, geologic, and geochemical aspects of the site must be understood and this knowledge input on the tailing management system selection and design.

Throughout the GEIS wordage regarding the effects of tailings solution seepage include "potentially", "could be", "site-specific", "conservative assumptions", "items not considered", "upper limit impacts", etc., yet definitive conclusions are drawn in Chapter 12 as to how regulatory items should be set forth. Data for performing a reasonable analysis are not presented and methods of analysis are often not consistent with current state-of-the-art analytical techniques, assumptions in other parts of the GEIS text, nor conditions and observations in actual tailings disposal practice.

Based on the itemized comments in Attachment I "Specific Comments" and Attachment II "Comments on Appendix E", as well as other assessments discussed herein, it is recommended that the criteria in Chapter 12 be made more consistent with the results of the model study; namely that more emphasis be placed on the site specific nature of the problem and not on the selection of one primary encompassing solution. Recommended new wordage for Item 6, Chapter 12 is presented later herein.

DEFICIENCIES IN MODEL SITE

In Chapter 4, a model site is discussed as a base condition, but the geochemical characteristics and surface geologic characteristics of the soils and/or rocks at this site are not discussed in detail. These are extremely important factors in the selection of tailings disposal sites and management systems for groundwater protection and in assessing the environmental impact of the tailings disposal system.

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LACK OF SITE-SPECIFIC CONSIDERATIONS IN IMPACT ASSESSMENTS

In Chapter 6 wordage such as "...seepage from tailings ponds could add heavy metals, suspended solids, radioactive contaminants and soluble salts to surface water..." are presented but the data throughout the text do not support this contention. A further quote from Chapter [illegible] "seepage from contaminated groundwater would not be likely to reach the spring and stockwatering impoundment until 80 years after mill operations have ceased (Appendix E) after which time the spring water entering the impoundment 1 would contain materials from the tailings pond." These statements are based on the assessment of the model in Appendix E. However, the model in Appendix E as discussed in Appendix E-1 and E-2 did not consider geochemical aspects. Appendix E-3 contains discussions regarding the geochemical aspects, but this model makes overly conservative assumptions regarding site conditions and the movement of toxic elements.

Specific comments regarding Appendix E are contained in Attachment II to these General Comments. Of particular note is the fact that the analysis did not consider lateral dispersion and no credit was given to adsorption, precipitation or ion exchange with contaminants in route. From our experience, these mechanisms contribute significantly to the reduction in the concentrations of contaminants in downstream areas, specifically when the subsoil conditions are geochemically adequate to cause this mechanism to occur. At the Split Rock Mill of Western Nuclear in Jeffery City, Wyoming, the increase in pH of the tailing solution by flowing through alkaline soils caused the precipitation of the iron and manganese and prevented their movement downstream; and contributed significantly to the trapping of other toxic elements including uranium and arsenic by adsorption and co-precipitation(1). A similar condition existed at the proposed Kerr-McGee Nuclear Corporation mill in the South Powder River Basin where it was estimated that neutralization of liquid seepage occurs within three (3) inches of flow through the soil, precipitating heavy metals and absorbing radium and uranium by the clay fractions(2).

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(1) Reference; Taylor, Michael J. and Antommaria, Phillip E., "Immobilization of Radionuclides at Uranium Tailings Disposal Sites", Proceedings of a Symposium on Uranium Mill Tailings Management, Volume II, November 20-21, 1978.

(2) Reference: Supplementary Material to the Environmental Report, South Powder River Basin Mill, Converse County, Wyoming, NRC Docket No. 40-8647 August 1977.

Consideration of these mechanism would result in different conclusions from the analysis in Appendix E-3.

The analysis in Appendix E-3 also indicates that the sulfates may move downstream. Although this may occur, it does not contribute a significant health problem. As discussed in Appendix E-3 "although neither of these contaminants (calcium and sulfates) poses a serious health problem, calcium makes it hard for soap lather and <u>excessive</u>(3) sulfates have a laxative effect. The case for isolating tailings and tailings solution based on the potential for movements of sulfates in often sulfate rich waters in uranium districts does not appear to be technically substantiated.

The above assessment is again supported by statements made in Chapter 6 in that "the impacts of uranium milling operations on groundwater are generally site-specific because of regional and local variations in geology and hydrology and thus are difficult to discuss on a generic basis" and is further supported by a statement made in Chapter 8 that "Satisfactory solutions to tailings waste disposal problems are highly dependent upon site-specific factors, such as climate, topography, and geology. The specific combination of elements producing an optimal tailings disposal program must be developed on a case-by-case basis, taking into account site-specific features." This is consistent with the conclusions above and the general remarks regarding the seepage associated with tailings disposal. However, it does not appear to be consistent with the conclusions drawn in Chapter 12.

<u>CURRENT DISPERSION MODELING METHODS NOT CONSIDERED</u>

In Chapter 6 a statement is made that "current methods of predicting movement and dispersion of contaminants do not permit accurate determination of impact on groundwater." This is not consistent with the significant amount of work which has been ongoing in the industry. In the NRC Environmental Impact Statement on the Split Rock Mill in Wyoming (Docket No. 40-1162) computer models, testing procedures and model calibration

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(3) Emphasis added.

using site-specific data are discussed as applied to a real problem. Additional work is required to make these models more generic, but they can be utilized on a site-specific basis to understand excursions regardless of tailing management systems utilized at the site. The site should be understood from a hydrologic, geologic, and geochemical standpoint and the available analytical tools applied to understand this mechanism. Then, a management system can be selected which will protect the groundwater from contamination.

SITE-SPECIFIC ASPECTS OF BARRIER SYSTEMS NOT CONSIDERED

In Chapter 8, alternatives for mitigating impacts of milling operations are discussed. The criteria regarding tailings disposal is stated as "reduction or elimination of impacts from groundwater". Several tailings area preparation methods are discussed to accomplish these results including:

- o No treatment
- o Soil compaction
- o Clay liner
- o Synthetic liner

Several alternates including these tailings area preparations are discussed with an emphasis on the barrier liner concept; little discussion is, however, presented as to the geologic and/or geochemical aspects of the site and the role these factors play in an effective tailings management system. As stated in Section 8.4.1.4 "Most of the alternative programs conservatively provide protection by isolating tailings and tailings solution through use of bottom liners and location of groundwater formations." "It may be possible to ...eliminate liners altogether."

Although potential for liner elimination is provided in the GEIS, a proper handling of the issue is not provided. This understanding of the site-specific issue is important, whether a liner barrier is installed or not. Most, if not all, liners leak and have the potential for significant failure. If they do leak or fail, it is important to understand the consequences. In certain cases, liners will not be required at all. At a site where a homogeneous chemically active sand exists with moderate permeability, the development of mechanism whereby the radionuclides and toxic elements are precipitated, adsorped and/or otherwise removed from the solution makes the liner a redundant system. In other cases, a liner alone is not sufficient. For instance, if the subgrade condition consists of open fractured rocks in direct communication with the groundwater, the potential for liner failure may be increased and the consequences of liner failure are higher. A false sense of security could be developed by the installation of minimal liner system. Extra precautions during liner installation, accurate monitoring system, or collection back-up systems may be required.

Seepage barrier liners have several other disadvantages including creating:

- o Difficulty in achieving access for reclamation cover by trapping water in the tailings and reducing the tailings in-place strength to support equipment. Also difficulty will occur at the time of decommissioning because of this trapped water.
- o Greater danger of impoundment failure where recycling to the plant is not possible and storage of larger quantities of tailings solution are required.
- o The requirement to treat the recycled water for use in the plant if sufficient storage area is not available for the entire volume of storage.

Advantages of barrier systems include:

- o The reduction of seepage to nonreceptive soils or fractured rock system.
- o Protection of groundwater or surface water aquifers which are immediately adjacent to these nonreceptive soil systems.
- o Savings of water for plant use if water is a problem.

But all of the above advantages and disadvantages are related to site-specific conditions as well as site milling operations and are not generic in nature.

LINER FAILURE AS AN ACCIDENT NOT CONSIDERED

Discussions of liner failure and the consequence of these failures are not discussed in Chapter 7; yet liner failure can provide a significant contribution to environmental damage if failure occurs under adverse site conditions. As stated in Chapter 9 "...synthetic liners have been known to fail because of subsoil settlement, puncture by rocks, splitting at seams or entrapped air bubbles." To state that proper installation can eliminate this problem shows naivety of the construction and mining industry. Even if a barrier liner is installed, the knowledge of the mechanism of what will happen if the liner fails is a part of the tailings disposal system design. Flow of seeping water through a subgrade of chemically active sands, silts or clays will significantly mitigate the effect of seepage and add to the benefits of the overall system, eliminating the need for extensive monitoring or backup collection systems: conversely seepage through open fractured rock will do little to mitigate the effects of this seepage.

ADVERSE EFFECTS OF BELOW GRADE DISPOSAL

In Chapter 8, the majority of the alternates discussed are below-grade, near-surface showing preference for this method of disposal. It is realized this preference is primarily related to a generic concern for post-operational protection of the tailings from erosion forces, but is a site-specific problem regarding aquifer protection. Often the below grade disposal results in the tailings being closer to the groundwater, thereby increasing the potential for aquifer contamination. A higher elevation of stored tailings may allow greater potential for radionuclide and toxic element treatment in natural soils (prior to reaching the groundwater), or allow more effective design of a backup collection or monitoring system.

EXAMPLE SITE-SPECIFIC METHOD OF TAILINGS MANAGEMENT SYSTEM SELECTION

As an alternate approach to tailings management system selection for groundwater protection, a method should be adopted which is keyed to the site conditions. An example system of reviewing alternate site treatment methods is illustrated on the attached tables to demonstrate the site-specific aspects of tailings management. Four key factors are rated for varying site subgrade conditions and for varying tailings area preparations. The factors include:

- o Potential for Hydrologic Communication with Groundwater
- o Potential for Toxic Element Movement
- o Containment Failure Consequences
- o Cost Factor

A rating of 1 to 10 is provided for each key factor as it relates to each subgrade condition against each area preparation method. The rating is subjective and based on experience.

When all factors have been rated, the values are summed to provide an evaluation of the method of tailings area preparation for the various subgrade conditions as shown on the final attached tables. This type of site related evaluation shows several important points. First, any type of liner on faulted, fractured or weathered rock does not in its self provide a very highly rated system. Second, installation of liners over geochemically active clay, silts or sands does little to improve the rating. Third, liners (or combination systems) are a necessity over gravels or other highly permeable deposits.

This example system is provided to show the site specific nature of tailings management system selection for groundwater protection; and to demonstrate that single all encompassing solutions such as barrier liners are not appropriate. A more complex and site specific rating system could be developed and is recommended for the GEIS.

RECOMMENDED REVISED LANGUAGE FOR ITEM 6 - CHAPTER 12

Since the tailings management system selection and design is a site-specific problem and the major technical issues are related to isolation of tailings and protection of groundwater quality rather than reduction of seepage, it is recommended that Item 6 in Chapter 12 of the GEIS (and Criteria 5 of the Regulations) be modified to read as follows:

> "The specific method or combination of methods of tailings disposal systems for mitigating toxic materials migration must be worked out on the site specific basis. The system shall be selected and designed to minimize, to the maximum extent reasonably achievable, the movement of toxic materials into the groundwater beyond the mill property boundary if such movement would create adverse health affects. Liners may be appropriate in some cases to protect groundwater quality and inappropriate in others. For instance, where natural soils provide an effective barrier against migration of harmful concentrations of toxic materials into or through the groundwater beyond the mill property boundary, barrier liners will not be required. Site specific tests and analysis conducted in accordance with prudent scientific methods shall be provided as appropriate to assess the impact of the proposed tailings disposal system and allow the staff to evaluate the effectiveness and benefits of the proposed system.

SUMMARY

The stipulation that isolation of tailings and tailings solution as a primary method of tailings disposal is not warranted. Isolation may lead to a false sense of security that a seepage barrier system has been installed and all problems solved; or could be a redundant system where the liner does little to improve the situation. It is better to review the site, understanding the hydrology, geology and geochemical characteristics of the subsoils or rocks and select the tailings management system based on a thorough understanding of the mechanisms involved. If a liner is warranted to minimize the potential for groundwater quality deterioration, it should be designed and installed understanding the potential and

consequences of failure of that liner and taking steps to mitigate that potential and/or consequences. No treatment or treatment consisting of compacting the soil which forms the bottom of the pond can be a more effective mechanism to protect the groundwater quality than a synthetic liner applied indiscriminately for isolation of tailings and tailings solution. Conversely, installation of a liner alone in certain circumstances may not be sufficiently adequate to provide the needed protection of the groundwater quality. Each site should be reviewed on a site specific basis and a program implemented to properly select and achieve the most advantageous method of tailings disposal for that particular site.

The proposed change in the draft GEIS and new criterion would make tailings disposal consistent with the common NRC and uranium industry objective of protecting groundwater quality, and will also provide a prudent scientific approach to tailings disposal system selection and design. The data and analysis necessary to implement this approach must be of high quality and obtained with prudent scientific methods. The industry has the ability to apply these methods and will do so if the regulations allow the flexibility to implement an optimum system based on this quality data. An educational process to guide industry to achieving this end is feasible without rigidity in regulations and the stipulation of a single solution to a complex problem.

KEY:
10 - Low Potential
1 - High Potential

EXAMPLE RATING TABLE
FACTOR NO. 1
POTENTIAL FOR HYDROLOGIC COMMUNICATION WITH GROUNDWATER

Tailings Area Preparation	None	Soil Compaction	Clay Liner	Synthetic Liner	Collection System	Comments
Site Subgrade Conditions:						
<u>Rock</u>						
o Solid-Impervious	10	N/A	N/A	N/A	N/A	
o Faulted	1	N/A	6	8	3	
o Fractured and Jointed	1	N/A	7	8	3	
o Weathered	3	N/A	7	9	5	
<u>Soils</u>						
o Clays and Silts						
- Homogeneous	8	9	10	10	7	
- Layered	7	8	9	9	8	
- Geochemical Charac. (Active/Non-Active)	7/7	8/8	9/9	9/9	7/8	
o Sands						
- Homogeneous	5	6	8	9	8	
- Layered	6	7	8	9	8	
- Geochemical Charac. (Active/Non-Active)	5/5	7/7	8/8	9/9	8/8	
o Gravels	2	3	8	8	9	

KEY:
10 - Low Potential
1 - High Potential

EXAMPLE RATING TABLE
FACTOR NO. 2
POTENTIAL FOR TOXIC ELEMENT MOVEMENT

Tailings Area Preparation	None	Soil Compaction	Clay Liner	Synthetic Liner	Collection System	Comments
Site Subgrade Conditions:						
Rock						
o Solid-Impervious	10	N/A	N/A	N/A	N/A	*Non-failure over Failure
o Faulted	1	N/A	8	8/5*	4	
o Fractured and Jointed	1	N/A	8	8/5*	4	
o Weathered	2	N/A	8	8/5*	4	
Soils						
o Clays and Silts						
- Homogeneous	8	9	10	10/10**	8	**Redundant System
- Layered	8	9	10	10/10**	8	
- Geochemical Charac. (Active/Non-Active)	9/6	10/7	10/8	10/10**	9/8	
o Sands						
- Homogeneous	7	9	9	10/8	7	
- Layered	6	8	8	10/8	7	
- Geochemical Charac. (Active/Non-Active)	9/3	9/6	10/7	10/9	8/8	
o Gravels	3	5	8	10/5*	9	

KEY:
10 - No Consequence
1 - High Consequence

EXAMPLE RATING TABLE
FACTOR NO. 3
CONTAINMENT FAILURE CONSEQUENCES

Tailings Area Preparation	None	Soil Compaction	Clay Liner	Synthetic Liner	Collection System	Comments
Site Subgrade Conditions:						
<u>Rock</u>						
o Solid-Impervious	10	N/A	N/A	N/A	N/A	
o Faulted	1	N/A	1	1	1	
o Fractured and Jointed	1	N/A	1	1	1	
o Weathered	3	N/A	2	2	1	
<u>Soils</u>						
o Clays and Silts						
- Homogeneous	9	9	9	9	9	
- Layered	8	8	8	8	8	
- Geochemical Charac. (Active/Non-Active)	9/8	9/8	9/8	9/8	9/8	
o Sands						
- Homogeneous	8	8	8	8	8	
- Layered	7	7	7	7	7	
- Geochemical Charac. (Active/Non-Active)	8/7	8/7	8/7	8/7	8/7	
o Gravels	3	3	3	3	3	

KEY:
10 - Low Cost
1 - High Cost

EXAMPLE RATING TABLE
FACTOR NO. 4
COST FACTOR

Tailings Area Preparation	None	Soil Compaction	Clay Liner	Synthetic Liner	Collection System	Comments
Site Subgrade Conditions:						
Rock						
o Solid-Impervious	10/1*	N/A	N/A	N/A	N/A	*Nonexcavation over excavatio
o Faulted	9	N/A	6	5	4	
o Fractured and Jointed	8	N/A	5	4	4	
o Weathered	8	N/A	5	4	4	
Soils						
o Clays and Silts						
- Homogeneous	9	8	7	6	2	
- Layered	8	8	7	6	1	
- Geochemical Charac. (Active/Non-Active)	9/7	8/9	7/6	6/5	1/1	
o Sands						
- Homogeneous	9	8	7	6	6	
- Layered	8	7	6	6	5	
- Geochemical Charac. (Active/Non-Active)	9/7	7/6	6/5	4/4	5/5	
o Gravels	9	7	6	4	7	

KEY:
The higher the total the
more advantageous the system.

EXAMPLE RATING TABLE
SUMMARY EVALUATION

Tailings Area Preparation	None	Soil Compaction	Clay Liner	Synthetic Liner	Collection System	Comments
Site Subgrade Conditions:						
<u>Rock</u>						
o Solid-Impervious	40/31*	N/A	N/A	N/A	N/A	*Nonexcavation over excavatio
o Faulted	12	N/A	21	22/19*	12	*Nonfailure ov failure
o Fractured and Jointed	11	N/A	20	21/18	12	
o Weathered	16	N/A	22	23/20	14	
<u>Soils</u>						
o Clays and Silts						
- Homogeneous	34	34	36	35	24	
- Layered	31	33	34	33	25	
- Geochemical Charac. (Active/Non-Active)	34/29	35/32	35/31	34/30	26/25	
o Sands						
- Homogeneous	29	31	32	33	29	
- Layered	28	29	29	32	27	
- Geochemical Charac. (Active/Non-Active)	31/22	31/26	32/27	33/29	29/28	
o Gravels	17	18	25	25	28	

ATTACHMENT I

Specific Comments on
Draft Generic Environmental Impact Statement
on Uranium Tailings

SUMMARY

Page 3

It is noted that the health impacts are stressed as Rn-222, Radium 226 and Lead 210 in the tailing pile. None of these elements are transmitted from the tailings solution through geochemically active soils.

Page 4

It is indicated that Radium 226 and Lead 210 are problems when ingested in pathways. Since they do not move in geochemically active soils, ingestion pathways are unlikely.

Page 7

At the bottom of the page under Groundwater, the statement indicates that seepage of such solutions can potentially adversely affect groundwater aquifers. Use of this type of language throughout the text does not warrant the conclusions in Chapter 12.

Page 8

The first statement on the page in the first paragraph indicates that the transport of toxic elements and tailings solutions is a complex function of many parameters. The solution to selecting the right tailings systems is also a very complex solution and consequently should not be dictated by a singular solution.

The second paragraph on that page indicates that "some heavy trace metals (may not) be moved from (the tailings) by adsorption" in the soil. However, other mechanisms such as coprecipitation of some of these elements may remove them from solution and prevent transport further downstream". Experience indicates that at some sites these elements are not moving or moving at a very slow rate.

Page 8

It is noted that the wordage again is "using conservative assumptions" about transport parameters. This should not be the basis for statements regarding isolation of tailings later in the GEIS.

Page 14

At the center of the page, the statement is made that "Generally the staff has weighed alternatives in terms of broad criterion that tailings should be isolated so that conditions at the disposal site will be reasonably near those of the surrounding environs". Liners may not meet these types of criteria for certain sites; or may not be required to meet the criteria at other sites. They can present a discontinuity in the environ which is suceptible to future degradation with the potential for disperals at a later time. Liners are not passive monitoring modes since they can deteriorate and fail.

Page 19

The GEIS indicates that the staff concludes that the most effective way to reduce potential groundwater contamination associated health effects is to reduce the amount of moisture available to carry toxic contaminants away from the impoundments. It is inconsistent with the discussion that most of radionuclides and toxic elements remain fixed. Selenium, arsenic and molybdenum also have potential for not moving. Sulfates and chlorides could move; however, these do not have excessive health effects. At this stage of the GEIS, it appears that toxic elements are being used synonymous with sulfate which is not appropriate.

Page 20

The GEIS indicates that the disposal is a site specific'phenomena and should be considered such. This is an acceptable statement and should be expanded upon rather than put in as an after thought.

Page 23

Discussion is presented regarding reduction in seepage to be achieved "to the maximum extent reasonably achievable", yet at the bottom of the page the primary method of protecting groundwater is indicated "as isolation of tailings and tailings solution from groundwater, (with) disposal involving contact of tailings disposal with groundwater might be acceptable if supporting tests and data and analysis demonstrate that the proposed disposal and treatment methods protect groundwater quality." A primary method should not be stressed and then qualify it by saying that other methods are appropriate if appropriate data is provided. Each system should be evaluated on a site specific basis.

CHAPTER 1 - INTRODUCTION

Pages 1-3

Under Section 1.3, at the bottom of the first paragraph, the GEIS indicates that "to do this, a range of upper limits for site specific impact is presented." If the upper limits of impact are presented, then the conclusion should not be based on these upper limits, rather they should be based on a more realistic assessment of the overall problem. Again, a more site specific assessment is proposed, rather than stressing one specific technique for a tailings disposal.

CHAPTER 4 - ENVIRONMENT OF THE MODEL REGION

The model shows tailings siting on alluvial deposits. We question the typical nature of this disposal system. As discussed in the general comments, many situations can exist on the site. A rating factor for a tailings area preparation method as compared to the site subgrade conditions appears more appropriate than assuming a model condition of tailings siting on alluvium adjacent to a river. This may be a significantly worse case condition than is typical for the industry.

Appendix B - (As Referred in this Section)

Comments regarding Appendix B are as follows:

The concentrations of arsenic, barium, cynide, selenium, molybdenum, and lead are assumed to be so small (0.001 parts per million) that it should not be considered. Yet, the constituents of the tailings water as set forth in Chapter 4 for the model include significant values of some of these elements. This is further exemplified in Chapter 5 by Table 5.3 where the chemical characteristics of the acid leach or carbonate leach look different than those set forth in Appendix B.

A significant ommission in Chapter 4 is that there is little discussion concerning the subgrade characteristics or geology of the near surface rock systems and/or the geochemistry aspects of the site. These are both important elements to tailings management.

CHAPTER 5

The model discussions assume no environmental controls. These apparently include little evaluation of the geochemical characteristics of the movement of the toxic elements through the unsaturated soil media underneath the tailings pond. Although some attempt is made at this in Appendix E discussed under Chapter 6, the model mill assumes relatively low levels of environmental control and apparently does not assess the natural phenomena of environmental control that may be occurring.

CHAPTER 6

Page 6.6

Under 6.2.4 at the bottom of that paragraph, the GEIS indicates that a sensitivity analysis was carried out for groundwater impact by varying the important parameters over an appropriate range. Nowhere in the GEIS are important parameters defined and since the geochemistry is neglected, including precipitation, coprecipitation and adsorption mechanisms, it is difficult to see how important parameters have been varied to study these effects.

Section 6.2.4.1.2

The GEIS discusses that during operations, seepage from the tailings pond could carry heavy metals, suspended radioactive contaminants and

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soluble salts to the surface waters. This is a site specific phenomena and should not be stressed in the GEIS. In many cases, the seepage from the tailings pond will not carry heavy metals to the surface water since the geochemical activity is occurring within the soils immediately beneath the pond, thereby precluding the movement of the toxic element. The GEIS seems to hedge by using words such as "could add" but the impression is left that these operations have the definite potential for causing this detrimental affect. Under the proper situations, this may be the case. Conversely under the proper natural conditions, this will not be the case. It does not seem appropriate to stress this type of negative impact in the GEIS.

Further evidence of this is set forth on page 6-7 where statements are made such as "seepage from the contaminated groundwater would not be likely to reach the spring at a stock watering impoundment until 80 years after mill operations have ceased, after which time the spring water entering the pond would contain materials from the tailings pond." Again this is a very site specific situation and leaves the impression that such movements could occur in any sites which is not the case. Even at the model site, it is not known whether movements will or will not occur since no information is given about the geochemistry or near surface geologic characteristics of the site.

<u>Section 6.7</u>

The site specific nature of the impact is further supported by the statement "the impacts of uranium milling operations on groundwater are generally site specific and thus are difficult to discuss on a generic basis". Yet, the other sections of the GEIS continue to discuss the impact and come to a conclusion of required or recommended isolation based on these assumed impacts.

<u>Section 6.7</u>

A statement indicates that the current methods predicting movement and dispersion of contaminants do not permit accurate determination of impacts on groundwater. This is not correct. State-of-the-art work is proceeding in this area and much is being learned by calibrating models with on site observations. It is not appropriate to draw final conclusions in the GEIS based on the fact that the state-of-the-art is not presented in standard design manuals or textbooks. Many problems are solved on a site specific basis using prudent scientific or state-of-the-art methods and should not be excluded by the GEIS.

Page 6-77

The statement is made that seepage of such solutions can potentially adversely affect groundwater or drinking water supply. This statement does not appear appropriate in the GEIS in the light of the other statements concerning site specific nature of the problem. This is followed by statements such as "natural subsoil conditions will tend to remove many heavy metals or radionuclides such as radium and thorium from the tailings pile", but is discarded by such statements as "some heavy trace metals such as selenium, arsenic and molybdenum may form ions which behave similar to anion contaminants such as sulfates which do not tend to be removed by sorptions", but no credit is given for precipitation or coprecipitation. On-site obserations have been made where arsenic and selinum and molybdenum have not moved even though many years of operations have occurred. Sulfates may have moved at some sites but it is often difficult to tell where the sulfates are moving from the tailings water or whether the typical sulfate rich groundwater which existed in many uranium milling areas is contributing to the existing concentrations.

CHAPTER 7

The potential for liner failure is not discussed in this chapter in any great detail, yet liner failure and specific situations such as liners over extremely pervious foundations adjacent aquifers could be a significant path of radiotoxic and toxic element contaminations. Liners do fail. Without an assessment of the consequences of these failures, the liners in themselves should not be considered as a cureall for tailings management to protect groundwater.

CHAPTER 8

The various alternates which are discussed apparently are "to reduce or eliminate impacts on groundwater". Yet, the geochemical aspects of each system are not discussed and more emphasis is placed on seepage barrier alternates rather than allowing natural purification of tailings water in soils.

Page 8-18

The GEIS states "most of the alternate programs conservatively provide groundwater protection by isolating tailings and tailings solutions through the use of bottom liners in locations and locations above groundwater formations. It may be possible to treat tailings to allow contacting sands and slimes with groundwater or to eliminate liners altogether. Data from tests performed on site specific soils hydrology and geology would be needed." Assessment of treatment methods and applying prudent scientific methods to data procurement and analysis should be stressed more in the GEIS rather than stressing isolation barrier systems which can be taken as a cureall and indiscriminantely and often improperly applied. Liners and barrier systems are a very important aspect of tailings management systems to protect groundwater, but should be applied where and when needed; not indiscriminantely as redundant systems and/or in situations where their use alone does not constitute safe and proper tailings management systems to protect groundwater.

CHAPTER 9

Page 9-16

The statement is made that synthetic liners have been known to fail, but if properly installed, will not fail. This is a naive position. If liners failed in the past they will fail again. Field conditions for installation are not always so good that leakage and failure will not occur. Seepage from the pond can exist in the underlying subgrade. It is important that an understanding of the consequences of the seepage be incorporated in the tailings management program and/or collection and backup systems be employed if necessary to minimize the consequences of such failure. If the consequences of the seepage are minor, then the need for the liner in the first place should be questioned since it may be a redundant system. Disadvantages of liners exist such as (a) they trap water in the tailings solids and prevent access for reclamation or cause delays in decommissioning while the water evaporates, (b) they can cause excess water to be accumulated in the impoundment resulting in a greater potential for sudden tailings solution escape by breaching through embankments, (c) they concentrate the water and cause greater evaportion, thereby, causing a greater concentration of radionuclides in the pond with inherent potential for spillage. Liners do have their place in tailings management systems to protect groundwater and are quite effective in saving water and preventing movements of toxic leachates into non-receptive subgrades.

Page 9-13

Again the accident analysis does not consider failure of the liner. This is an important aspect and should be considered in that it may (1) show that a liner system is not adequate under certain conditions, or (2) show that the liner is only a redundant system and is not needed if the soil characteristics are adequate.

Page 9-42

It is stated that the extent of impacts is related to extent of seepage of tailings solution. This is not the case. The extent of impact is based on the geochemistry and geologic characteristics of the site as well as the extent of seepage. On many sites, the extent of seepage does not affect the impact of the seepage since the site has the necessary characteristics to geochemically mitigate migration; neither the tailings, tailings solution nor toxic elements move outside the restricted area.

CHAPTER 12

Page 12-2

Item 6 discusses the need to isolate tailings to prevent detrimental impacts but still leaves the door open for site specific evaluations. The emphasis should be more on site specific evaluations and not on the reduction of seepage alone. If the industry or the NRC begins to rely

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on "Maginot Lines" to protect groundwater quality, the consequences can be significant to the environment and the operating capabilities of the uranium miner.

Paragraph 12-20

The position of the NRC begins to waiver in the statement on this page where the GEIS states that "...the staff concludes that these (radioactive) materials can in most cases be effectively contained with combinations of impoundment liners and natural underlying soils...". Yet they go on to say "highly impermeable clay and synthetic liners drastically reduce the rate at which tailings solutions can seep from the disposal area and, hence, the rate at which toxic materials can escape to groundwater." These two parts of this section are incongruous based on the knowledge of the industry and various sample sites.

ATTACHEMENT II

Comments on Appendix E
Draft Generic Environmental Impact Statement on Uramium Milling

Appendix E has been reviewed for the purpose of determining if data and calculational techniques were sufficient to demonstrate a need for total tailings and tailings water containment. Specific comments follow.

(1) Appendix E is divided into three sections. The first section, Appendix E-1, shows calculations of seepage discharge from an unlined tailings pond. This is a simple water budget analysis and the methodology appears correct. However, on Page E-6, the document acknowledges that complex phenomena such as possible reduction in seepage because of the buildup of slimes and because of chemical reactions associated with seeping acidic solutions are not accounted for. There is substantial discussion in Appendix E-3 regarding chemical reactions which occur when acidic leachates react with calcareous soils. This suggests overconservatism in the basic assumption that seepage will not decline over a period of time. A specific non-uranium project experience has shown permeability decreases from about 10^{-4} centimeters per second to 10^{-7} centimeters per second due to chemical reactions in the bottom of the pond.

(2) Appendix E-2 addresses calculation of seepage water velocities in the subsoil. The simple mathematical model considered longitudinal disperion but did not take into account vertical dispersion. Consequently, the breakthrough curves for tailings pond seepage water shown in Figure E-2.2 are overly conservative. In fact, it is indicated in Appendix E-2 that consideration of vertical dispersion would spread contaminants over a wider and deeper belt allowing for greater mixing and dilution. This would decrease the concentration of contaminants.

(3) Appendix E-3 offers calculations of seepage water chemistry. The first part of this appendix discusses basic phenomena important to calculating contaminant movement through porous media. Diffusion,

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hydrodynamic dispersion, and sorption are discussed. Following the discussion of these basic principles, there is a statement that indicates that no accepted theory of solute movement encompassing all of the discussed phenomena of dispersal exists which can be used to predict the time rate of change in concentration of a solute. The appendix then discusses theories using only solid-phase sorption and those using convection, diffusion, hydrodynamic dispersion, and solid-phase sorption. Regarding the latter theories in which Equation 3 of the appendix is presented and which is used to predict the time rate in change of concentration of the solute some distance from the point of injection, the following statement is made: "In arriving at Equation 3, it is assumed that (1) the dispersion coefficient (D_m) accounts for both hydrodynamic dispersion and diffusion, (2) the porosity, permeability, and distribution coefficients of the exchange are constant, (3) equilibrium has been attained, and (4) the flow rate is constant." The appendix then states that those assumptions are not valid in the natural system. Thus the movement of solutes predicted by that theory is questionable. By using a finite element technique, spacial variability and parameters input to Equation 3 can be accounted for. The assumption that equilibrium is attained is not always realistic for natural systems. However, this modeling technique is far superior to one not considering distribution coefficients and should have been used for contaminant movement projection at the GEIS model mill.

The GEIS cites a reference by Pinder in which he modeled groundwater contamination in Long Island and found that dispersion coefficients were orders of magnitude larger than values obtained for flow in isotropic porous medium models in the laboratory. This fact is recognized by individuals modeling contaminant movement in porous media. No consideration is given in Pinder's work, however, to the concept of distribution coefficients. Furthermore, Pinder's study does not reject the theory of dispersion modeling but emphasizes obtaining site-specific data.

(4) On Page E-15, it is stated that in the attempt to predict movement of contaminants at the model mill, recourse to elaborate mathematical models seems inappropriate and that consequently only basic mathematical assumptions and the construction of a simple geometric model as shown in Appendices E-1 and E-2 were used in the analysis of the extent of groundwater contamination. Bearing in mind that Appendix E-1 addressed the rate of seepage based on a simple water budget analysis and that E-2 considered contaminant transport excluding sorption phenomena, this methodology appears grossly overconservative.

(5) Under the analysis of the model mill site, it is suggested that the concentration of dissolved substances in the mill discharge become increased by about 160 percent in the residual tailings pond liquid because of evaporation. There is no discussion on the fact that certain species within the tailings water become supersaturated and precipitate because of this increase in concentration. This phenomenon has been noted at operational mills. This leads to an overconservative estimate of the tailings solution chemistry.

(6) On Page E-18 under the discussion of iron, it is indicated that calculations made to predict the rate of spread of iron can be used for other contaminants as well. This is not a true statement; only species behaving geochemically similar to iron will move at about the same rate. Furthermore, it is unsupported that the concentration of iron will range between 1 and 10 milligrams per liter if the pH is between 6.0 and 8.0. It is suggested that the highest concentration of ferrous and ferric iron will be around 10 milligrams per liter. This is not supportable because it does not account for EH conditions and other coexisting aqueous species. The Davis and DeWiest reference cited suggests this is true for a solution containing 100 milligrams per liter bicarbonate and 10 milligrams per liter sulfate. This does not likely resemble the chemistry of water at the modelled mill site. There is also no discussion on the concept that once iron oxides precipitate, the solid phases formed are extremely sorptive materials.

(7) Also on Page E-18, there is a statement under the discussion of iron that the analysis performed is conservative because it did not consider lateral dispersion, adsorption, precipitation, or ion exchange. In the subject under consideration, these phenomena must be considered to provide a realistic estimate of contaminant movement.

(8) The discussion on manganese suggests that in natural waters the concentration of manganese is typically less than one-half that of iron. Based on that, the analysis in the GEIS assumed that after neutralization the manganese concentration would be five milligrams per liter. We are not dealing with natural waters. At the Split Rock Mill in Wyoming manganese was present in far less than half the concentration of iron at specific points of measurement. Here again, their assumptions are grossly overconservative.

(9) Under the discussion of selenium, they assume a concentration of 32 milligrams per liter in the tailings pond water at a pH of 2. At the Split Rock Mill, the tailings pond water contained 1.8 milligrams per liter of selenium at a pH of 1.95. The GEIS states that the geochemistry of selenium is poorly understood but it is known that it can form an anion similar to sulfate that will not be subject to cation exchange. The GEIS assumes that, in a worst case, no reduction of a selenium concentration will occur due to changing pH or ion exchange. At the Split Rock Mill concentrations of selenium changed by approximately an order of magnitude as the tailings pond water seeped through natural soils. Here again, the assumptions in the GEIS are grossly over conservative.

(10) Under the discussion of radium and thorium, the GEIS selected a conservative value for the distribution coefficient of radium in nearly neutral water at 10 milliliters per gram. In a study at the Split Rock Mill, a distribution coefficient of 100 milliliters per gram for a neutral solution was used. Here again, the assumptions in the GEIS are overly conservative.

(11) Under the discussion of other possible contaminants, it is suggested that arsenic would not be affected by pH and could be expected to follow concentration curves shown in Figure E-3.1. At the Split Rock Mill, arsenic is affected by pH and various adsorption/coprecipitation reactions. This is especially true when iron and manganese oxides precipitate in the interstices of natural soils. These oxides are a highly adsorbent material.

(12) In the conclusions to Appendix E, the GEIS states that no contamination of groundwater with radioactive material will occur because of seepage from the model mill tailings pond, but that contamination from sulfate, iron, manganese, selenium, and possibly other trace elements will occur. These predictions for iron, manganese, selenium, and arsenic are grossly over conservative and do not accurately reflect retardation by natural phenomena. Depending upon site conditions, it may be true that sulfate will move at approximately the same rate as an advancing front of groundwater. However, sulfates are not particularly deleterious to the use of the water. In fact, many of the natural waters in uranium mining and milling areas are rich in sulfates. Additions of the small amounts due to tailings disposal may not be deleterious to the use of the water.

(13) In summary, the approach taken in Appendix E is overly conservative and offers predictions of contaminant movement through porous media in excess of what can be expected when appropriate consideration is given to natural phenomena such as ion exchange, precipitation and adsorption.

Part III

C. Milling and Tailings Disposal Considerations

1. Management

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C. MILLING AND TAILINGS DISPOSAL CONSIDERATIONS

1. Management

SUMMARY

The draft Generic Environmental Impact Statement lists nine alternative methods of disposing tailings. However, the first alternative is indicated to be "unacceptable" and alternatives 7, 8 and 9 are stated to be "not feasible because of high costs and technological uncertainty and therefore will not be enforced." Consequently, under the draft GEIS, industry appears to be limited to a choice of five "acceptable" alternatives of the passive monitoring mode, numbers two through six. These five alternatives create inflexible requirements rather than site-specific solutions.

The problem is further complicated by the draft GEIS' failure to distinguish between "existing" and "future" operations. Before any consideration is given to applying the requirements of the draft GEIS to existing facilities, the economics and feasibility of retrofitting must be determined and included in the overall evaluation.

In addition, there are many site-specific factors which must be considered and included in the final GEIS to permit the setting of objectives that will allow much more flexibility in considering alternatives. The final GEIS should not set rigid technical requirements, but instead should allow the flexibility to utilize the best technology to develop and expand on alternative methods so as to adapt to site-specific situations.

COMMENTS

1. Page 1, Overviews, Text

"The staff has identified in its analysis a range of disposal methods, involving below-grade disposal of tailings that can meet these criteria. These include methods worked out with mill operators over the past year and represent a marked departure from past disposal practices." (Emphasis added)

Comment:

There are frequent references in the draft GEIS to the large number of alternatives considered. However, of the nine alternatives actually analyzed, alternative 1 is rejected as "unacceptable" and alternatives 7, 8 and 9 are rejected because of excessive costs and technological uncertainty. Four out of five alternatives require below-grade disposal. The statement "methods worked out with mill operators over the past year" should be documented as to how many mill operators and as to whether the methods involved are for new or existing operations. The draft GEIS does not distinguish between new and existing operations. Consequently, it appears all operations will be forced to meet regulations based on the draft GEIS. We believe such an approach to be unwarranted.

2. Page 8-7, Text

"Numerous strategies for attaining these objectives have been suggested. For purposes of discussion, elements of these proposed strategies may be classified into four categories:

(a) Preparation of tailings for disposal (some methods involve changes in mill operations);

(b) Location of the tailings disposal area;

(c) Preparation of the tailings disposal area; and

(d) Stabilization and covering of the tailings.

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"A list of alternatives broken down into these categories is presented in Table 8.2 None of these alternative methods in themselves represents a complete tailings disposal program; that is, each offers potential for solving one or several, but not all, of the problems identified above. They must, therefore, be combined to form a complete tailings disposal program, and it is obvious that numerous combinations exist. It would be extremely difficult to evaluate the full range of combinations; hence, a limited number of tailings disposal programs selected to incorporate the principal alternatives are described in Section 8.4. These programs are evaluated in later chapters.

"Satisfactory solutions to tailings waste disposal problems are highly dependent upon site-specific factors, such as climate, topography and geology. The specific combination of elements producing an optimal tailings disposal program must be developed on a case-by-case basis, taking into account site-specific features. (Emphasis added) The general analysis of alternative tailings disposal programs presented herein is primarily an illustrative exercise intended to support the establishment of various requirements to be included in regulations governing the development of site-specific programs."

Comment:

We concur with NRC that it would be extremely difficult to evaluate and incorporate the full range of combinations possible and necessary for existing operations. It would also be difficult, if not impossible, to try to develop a specific alternative for all milling operations which would be satisfactory to the regulatory agency and to the industry considering the site-specific economics involved. Mill operators should be permitted to develop programs which meet the objectives outlined in Section 8.3. This could be accomplished by permitting the regulatory agency flexibility to allow the use of the best technical expertise available to develop and improve on methods.

3. Page 8-17, Text

"8.4 Description of Tailings Disposal Programs. 8.4.1 Introduction. The specific measures discussed in Section 8.3 should be combined to form a complete tailings disposal program. Each Alternative offers potential for solving one or more, but not all, of the problems which must be addressed. For this reason, and because of interrelationships among the objectives of tailings disposal programs, the general approach adopted by the staff was to evaluate a range of complete disposal programs as opposed to evaluation of individual methods to achieve each objective exclusively. The tradeoffs, for example, between the desire to avoid contamination of groundwater and the advisability of isolating tailings from surface erosion for long-term stability can be more clearly illustrated by this approach."

Comment:

We believe site-specific considerations require an evaluation of individual methods utilized in various existing milling operations and operators should be afforded the flexibility to meet the specific measures outlined in Section 8.3 in any fashion which will produce the desired results.

4. Page 12-5, Text

"12.3.2.1 Active Care Mode. The staff concludes that although alternative 1 incorporates features which are an improvement over past practice, the alternative is unacceptable. It commits future generations to a prolonged obligation to care for wastes generated to produce benefits which those generations will receive only indirectly, if at all."

Comment:

While we agree that any active care mode that would significantly burden future generations without attendant benefit is unacceptable, we do not think the features in alternative 1 will necessarily result in such an active care mode. NRC is basing this active care requirement on its conclusion that an above ground tailings pile provided with ten feet of cover and revegetated will be so susceptible to erosion that it will rapidly deteriorate. If the vegetative cover is adequate, this is unlikely to be the case. Further, in those cases where erosion is apt to occur, it can be controlled by application of riprap or other means.

It is suggested that the above section of the text be changed to read as follows:

> "The staff concludes that Alternative 1 incorporates features which are an improvement over past practices and, if erosion is adequately controlled, it is acceptable to meet site-specific situations in conformance with specific measures discussed in Section 8.3."

5. Page 12-6, Text

> "In some cases, below-grade burial may not be feasible because of potential groundwater problems. The concept of below-grade burial may also be difficult to apply in areas of irregular terrain where the depth of soil overlying bedrock is not sufficient to permit excavating a pit without blasting large amounts of rock. Some excavation may be possible in such a case to reduce the size of embankments required, but disposal of the entire tailings volume below the surface of all points in the surrounding terrain may be impracticable. Alterantive 6 represents a scheme which, with the incorporation of the design and siting features delineated in Section 12.2.1.3, would provide protection virtually equivalent to below-grade disposal.

Comment:

NRC should be complimented for recognizing that site-specific considerations may make below-grade disposal unattractive and that there is a need to develop alternative methods to meet individual operations.

6. Page 12-6, Text

"Assuring long-term stability is a highly site-specific problem. For this reason, the staff has termed below-grade burial a 'prime' option, as opposed to a generally applicable requirement. In developing tailings disposal programs, applicants must evaluate a range of siting and design alternatives and give first consideration to alternatives that involve below-grade disposal. The most important factor in this connection is siting. Consistent with the first point under the proposed regulatory action of Section 12.2.1, primary emphasis must be given to long-term impacts of mill tailings, as opposed to consideration of short-term convenience or benefits, such as minimization of transportation or land acquisition costs. Before it would be reasonable to accept above-grade tailings disposal programs, a showing that good faith attempts had been made to locate alternate sites, which do not suffer from the kind of limitations described above that prevent below-grade burial, would have to be made. In any event, if an above-grade scheme is proposed, then the applicant must justify the proposal by demonstrating that it will provide reasonably equivalent protection from natural weathering and erosional forces."

Comment:

Once again, NRC recognizes the need for site-specific consideration by requiring companies to justify the location of alternate sites prior to accepting above-grade disposal programs. We submit, however, that economics and costs must also be included in the overall evaluation of above-grade schemes and the draft GEIS should be revised to elaborate on this point.

7. Page 12-2, Text

"Sufficient cover should be placed over the tailings to result in a calculated surface exhalation rate of radon resulting from the tailings of less than 2 pCi/m^2-sec. . . ."

COMMENT:

The NRC goes to great lengths in the draft GEIS to evaluate different aspects of the tailings cover problem, such as the necessary cover thickness, the effectiveness and stability of various cover materials, and the cost of applying the cover.

However, nowhere in the draft GEIS are the mechanical aspects of covering the tailings and their resultant costs addressed.

In most cases, applying cover to mill tailings is possible from an engineering standpoint, provided that the tailings surface has been prepared beforehand. One common method of preparing the surface is to let the tailings dry out for a period of time and then combine the slimes with enough fill to allow heavy equipment to operate safely on the surface. Experience has shown that approximately five feet of fill is required to stabilize the slimes sufficiently to permit equipment operation. Because the fill material combines with the slimes, an additional five feet of cover (for a total of 15 feet) would be needed to meet the final cover requirements proposed in the GEIS. Thus, the cost of excavating, hauling and grading the cover material could exceed that given in the GEIS by as much as 50 percent. The time needed for tailings to dry prior to reclamation and its effect on bonding costs are acknowledged by the NRC (p. 14-3). However, complexity and cost of covering and reclaiming the tails has not been addressed. These problems and associated financial impact deserve a thorough evaluation by the NRC.

PART III

C.2. EFFECTS OF NATURAL FORCES ON TAILINGS COVER STABILITY

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The minimum thickness of three meters of cover material which is proposed in the draft GEIS, as has been shown in Part III, Item A of these comments, cannot be justified on the basis of reducing the risks of lung cancer. In addition, the amount of cover material required for reducing radon emission is seriously overestimated in the GEIS. The calculations (Chapter 11, appendix P) are based on assumptions that do not agree with empirical observations made by the United States Environmental Protection Agency at a partially reclaimed tailings pile. Those measurements indicated that approximately three <u>feet</u> of earth cover reduced the radon emission by a factor of eight. This finding would imply a reduction by a factor of sixty-four for six feet and a factor of five hundred for nine feet (less than three meters). The cover used in that case was local soil and included no clay. For other comparable circumstances, a cover layer of three to four feet of local soil would reduce radon emissions to a level that would be within the <u>range</u> of natural background.

The other potential justification advanced in the draft GEIS for covering tailings piles with three meters is the need to reduce the risk of long-term wind and water erosion. Since the risk from radon emanation from tailings piles has been so grossly overestimated by NRC, the potential harmful effects of

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some erosion by wind or water do not appear serious enough to require a minimum of three meters of cover. See also, Part III, Item A. No specified covering can provide complete assurance against human utilization or intrusion at some future date, nor can it assure that there will not be some erosion at some time. However, in view of the long-term care programs set forth in the regulatory criteria of the GEIS and the myriad of factors which may affect erosion, basing conclusions on these concerns appears to be arbitrary and capricious without substantial evidentiary support.

The draft GEIS fails utterly to present any evidence or evaluation of the many factors which would effect wind and water erosion. For instance, the slope of the reclaimed tailings surface has a much greater effect on erosion than does the thickness of the cover material.

A hypothetical case assuming 20 feet of soil cover (with limited compaction) was examined. The 20-foot thickness represents the thickness of fill measured perpendicularly to the slope of the waste materials considered.

The attached Figure 1 presents the results of the erosion analysis performed for the hypothetical area. Figure 2 presents a comparison of slope gradient with the volume of fill required for construction. Comparison of Figures 1 and 2 illustrates that, as the downstream slope of the area is flattened, soil erosion is reduced but the volume of material required to create the final slope is increased.

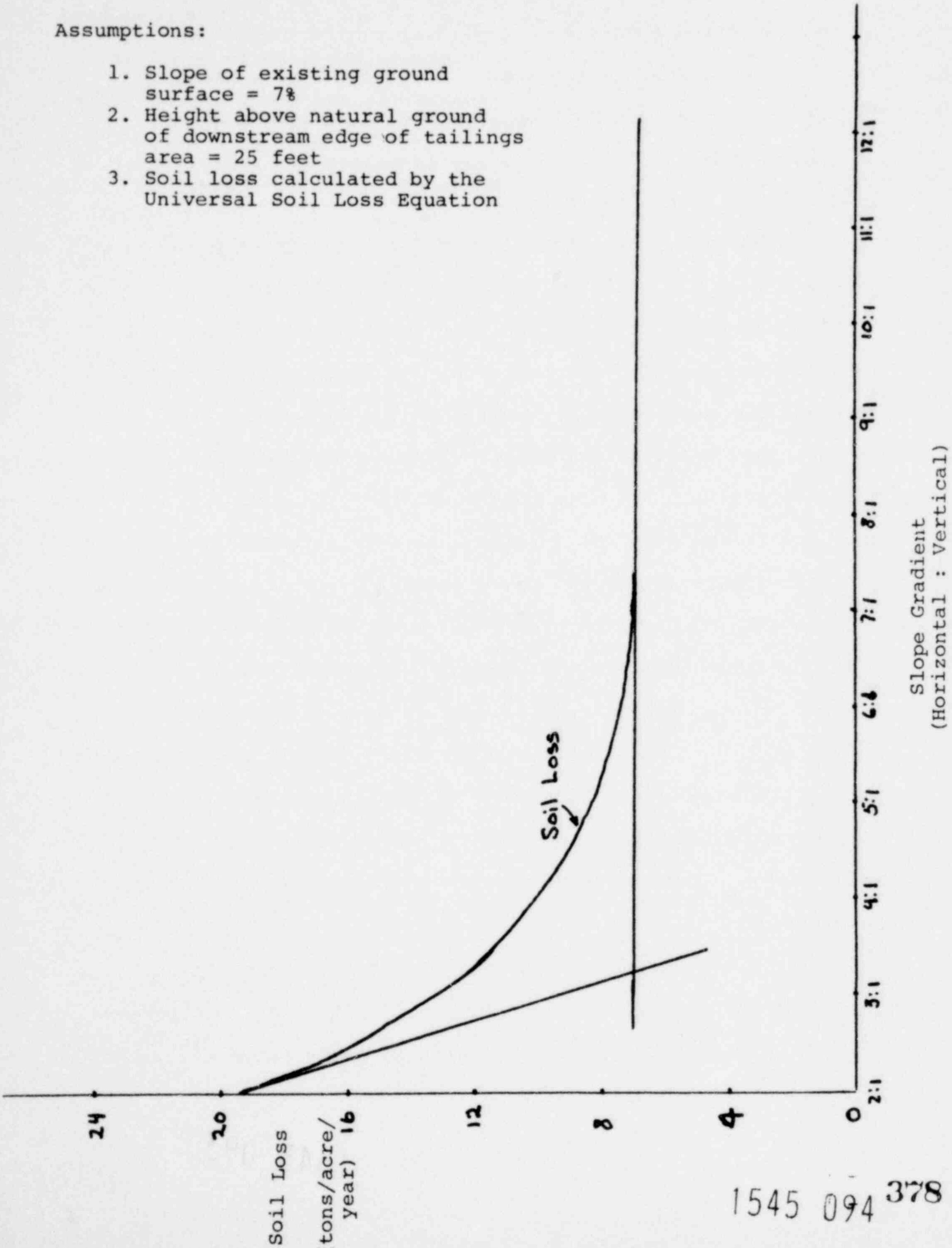
Estimated annual soil loss, calculated by the Universal Soil Loss Equation, is the amount of soil displaced per unit and not the total yield of sediment from a given unit area. The sediment yield from a slope is less than the total soil loss calculated by the Universal Soil Loss Equation.

As shown by comparing Figures 1 and 2, reducing the slope gradient from 6:1 will not substantially reduce the anticipated erosion rates without substantially increasing the volume of material required for construction. Establishment of adequate vegetative cover for erosion control is also difficult on slopes steeper than 4:1. Existing soil erosion rates for slopes between 4:1 and 5:1 are comparable to the anticipated rates for the area shown in Figure 1. Accordingly, a slope gradient between 4:1 and 5:1 is recommended for the downstream slope of the area.

Other physical factors which would also affect erosion by wind or water would be: (a) geology/soil compositions; (b) weather; (c) topography; (d) availability of fills; (e) engineering; (f) location; (g) monitoring; (h) reclamation (vegetation or riprapping). The complete failure of the GEIS to analyze these factors in relation to absolute and relative cover depth highlights the totally arbitrary nature of the NRC's minimum three meters cover requirements.

Finally, there is no scientific consideration in the draft GEIS of the likelihood, extent and effect of root penetration on the stability of the tailings cover material if that material is revegetated soil.

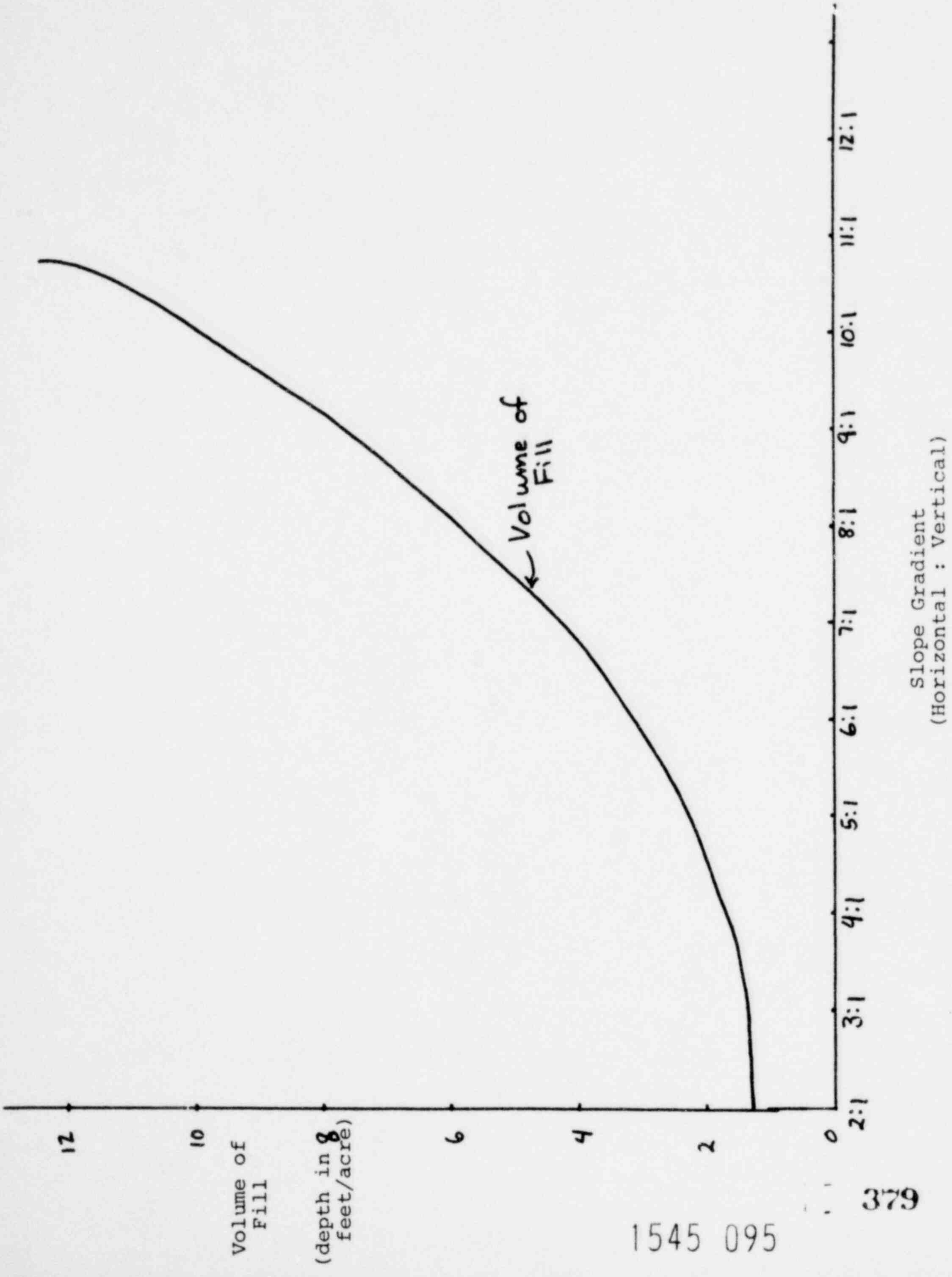
FIGURE 1 : Soil Loss Versus Slope Gradient



Assumptions:

1. Slope of existing ground surface = 7%
2. Height above natural ground of downstream edge of tailings area = 25 feet
3. Soil loss calculated by the Universal Soil Loss Equation

FIGURE 2 : Volume of Fill Versus Slope Gradient



PART III

C.3. COST UNDERESTIMATES

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As AMC stated previously, the draft GEIS relies heavily on NRC policy judgments rather than scientific analysis to develop the proposed regulations. NRC policy judgments also predominate in the draft GEIS treatment of costs. The basic approach in the draft GEIS is one of indifference to accurate cost estimates because, whatever the costs, they are judged to be within a range that is considered reasonable when compared with the perceived benefits.

The underestimation of costs often occurs when a project is not thoroughly engineered and understood down to the smallest details. The basic attitude towards costs and cost data in the draft GEIS has led almost inevitably to serious cost underestimation. This attitude is reflected in the statement on page 12-6:

> "These costs are still considered to be reasonable given the significant benefit associated with them (elimination of the need for continued active maintenance), and because they represent a very small fraction of the price of product or the cost of producing electricity."
> (Emphasis added)

Thus the draft GEIS assumes that detailed engineering and detailed cost estimating is not warranted. This rationale is invalid. The costs of compliance with certain of the proposed licensing criteria are truly significant and will noticeably increase the public's utility bills if these criteria are finally promulgated in their present form.

Throughout the draft GEIS, the argument is made that the estimated costs are reasonable because they represent only a small fraction of the price of yellowcake or the cost of producing electricity. This analysis is unacceptable for two reasons. First, a small incremental cost per kilowatt multiplied by a very large number of kilowatts results in a large absolute dollar burden on society. At one point, the draft GEIS states that, in the worst case, the cost of tailings cover would be less than 1% of the price of yellowcake. A 1% increase in the price of yellowcake and a corresponding increase of 0.1% in the cost of electricity translates into an additional cost to society of approximately $650 million for the 20 year period between 1981 and the year 2000 inclusive (using the figures in table 3.2 on page 3-2 of the Draft GEIS). A more realistic yellowcake cost increase would be 3% or more which would increase the total societal cost to $2 billion over the 20 year period or $100 million per year.

Secondly, money should not be spent merely because the expenditure can be made without bankrupting the uranium industry or because the cost can be passed on to the public in the form of increased charges on their electric bills. Each increment of expenditure should be justified by a resultant material increment in risk reduction. This concept, normally included in ALARA analysis, has been ignored in the draft GEIS. The intrusion of NRC policy judgments into cost analysis, and the conclusion that cost is reasonable if it represents only a small fraction of the price of yellowcake results in a cavalier treatment of costs in the draft GEIS.

The cost estimates for the Passive Monitoring Mode Alternatives described in the draft GEIS range anywhere from $6 million to about $16 million (or from 0.7 to 1.8% of the price of yellowcake) for the model mill. The draft GEIS does not indicate what level of costs or what percentage increase in the price of yellowcake beyond these figures would be considered unreasonable. What is apparent, regrettably, from a reading of Chapter 11 and Appendix K of the draft GEIS, is that the range of acceptable costs is deemed large enough to permit guess work and imprecision in placing a price tag on the recommendations of the draft GEIS.

When addressing the question of risk, the draft GEIS consistently takes the "worst case" or "conservative" approach. This compounding of conservative assumptions has the cumulative effect of grossly overstating the risks from uranium milling. On the other hand, when addressing the question of cost, the "best case" is consistently used. Quantities, unit costs, and project scope are frequently understimated or ignored resulting in significant bottom line errors in cost calculation.

We will now turn to some specific examples where the draft GEIS has inaccurately underestimated major costs.

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1. The draft GEIS acknowledges that cost estimates for alternative disposal modes at the model mill (Draft GEIS, p. 15, table 4) are "minimal in the sense that it was assumed that no untoward difficulties would be encountered" and that "unusual circumstances could increase the cost significantly" (Draft GEIS, p. 15). In addition, the draft GEIS acknowledges that the most highly variable costs appear to be those associated with earthwork and that earthwork represents a large portion of the costs for mill tailings disposal. For purposes of computing the costs of tailings management alternatives, however, the draft GEIS assumes that no unduly difficult earthwork will be required. (Appendix K-4 of draft GEIS at K-10). Only where the character of a procedure contained in one of the tailings management alternatives, *in itself*, raises or lowers the selected cost, is an adjustment of the unit cost made. This approach is unrealistic. Since it is anticipated that large amounts of material will be excavated, hauled and compacted, it would be more realistic to assume that some difficult and costly excavation and earthwork procedures will be encountered at some point and some projection of those costs should be included in the draft GEIS estimates.

2. Further, in selecting unit costs for various earthwork procedures, the draft GEIS consistently chooses values at the lower end of the projected cost range. (Appendix K-4 of GEIS at K-10, Table K-4.1). The cost figures from the actual experience of one AMC member company, attached as Exhibit A, indicate that the unit costs chosen in Table K-4.1 are frequently low by a factor or 2 or 3 or more. The use of unrealistically low unit costs

results in across the board errors in computation of the costs of alternative mill tailings management programs. AMC strongly urges the NRC staff to develop new cost information for a revised draft GEIS that will accurately reflect the cost to industry of the various earthwork procedures described in Table K-4.

3. Page K-26, Sec. 1.1 discusses the problem of achieving radon attenuation where clay is not available for use as cover material. It states that the required 9 million cu. yds. of material can be put into place for $9 million. A $1.00/cu. yd. cost figure is arrived at using $0.25/cu. yd. for spreading and compacting as per Table K-4.1. In addition to underestimating the unit costs, the draft GEIS overlooks the fill required for embankment slopes that are required in some form at most tailings sites. This oversight amounts to 4 million cu. yds. where the above ground disposal method is used based on a minimum slope of 5:1 -- the slope the draft GEIS asserts is prudent and conservative, as discussed on page 9-36. Thus the <u>total</u> cover material requirement is 13 million cu. yds. rather than 9 million cu. yds.

4. The draft GEIS also assumes cover material will be available on site, free of cost. We know of no mill site that has 13 million cu. yds. readily available on the site for excavation. In most cases the material for tailings cover will not be available free in the vicinity of the tailings site as assumed in the draft GEIS. Therefore, consideration must be given to probable cost involved in purchasing and hauling the cover material substantial distances. Even if we assume that the dirt is free on

site, and we limit the depth of excavation of this free dirt to 3 ft., we will need to remove 3 ft. of soil from 2,687 acres (or over 4 sq. miles) to obtain 13 million cu. yds. of material. After this has been done there undoubtedly will be regulatory requirements to resurface and revegetate this borrow area. There may well be additional requirements to segregate topsoil which will require an additional degree of excavation. Recent industry estimates indicate average revegetation cost would be on the order of $5,000 per acre, which in this example results in a total revegetation cost of $13,433,000.

5. Assuming that scraping up 4 square miles of dirt is not reasonable, another alternative would be to excavate a pit 60 ft. deep to provide the cover soil, but such a pit would require 134 acres plus the side slope areas. This 60 foot hole would be about 2200 feet square. The proposed criteria indicate that such holes should be backfilled and the next question which arises is -- where will this 13 million cu. yds. of fill come from?

6. AMC has been deeply involved in trying to determine what costs would be involved in complying with the draft GEIS tailings cover requirement. Indications are that dirt can generally be delivered for about $2.00/cu. yd. After assessing all available data we believe the total acquisition charge for the 13 million yards discussed above should be estimated at no less than $3.00/cu. yd. or $39 million. It is uncertain whether it would be cheaper to rehabilitate the 60 ft. pit or to

revegetate the 2,687 acres. For the moment we will assume each operation would cost about the same ($13 million). Thus, the total cost for this entire operation is not $9 million, as discussed in the draft GEIS, but will require $39 million for material acquisition, $13 million for placing and compacting and $13 million for revegetation or rehabilitation of the borrow pit. The total cost would be $65 million, over seven times the draft GEIS figure.

7. With regard to Item 4, Evaporation Pond, on page K-6, the total cost of $1.72 million for 40 hectares (or 100 acres) appears to assume a perfectly level site, free dirt, no pipelines or pumping facilities, no access roads, and no weather protection costs. When this total scope of work is considered, it will undoubtedly double the cost.

8. With regard to site decommissioning, Table K-7.1 states that the buildings and machinery can be removed without cost, i.e., that the salvage value will equal the cost of removal. This assumption might be valid for commercial warehouse-type buildings but not in the uranium milling context where the proposed criteria would require that heavy concrete foundations be broken up and hauled to the tailings pond. According to the cost data of one of the leading engineering contractors, the demolition cost for concrete is $20/cu. yd. Assuming the hauling and disposal cost for this concrete would be $10/cu. yd., then the total cost for this item alone is about $250,000. Another major engineering contractor estimates decommissioning costs

including building and machinery removal and reclamation, to be 6.5% of the capital cost of the mill. Thus demolition of a $30 million mill would cost $1,950,000.

9. In summary, it is AMC's position that the draft GEIS assumption of <u>no cost</u> for building and machinery removal is not valid. We suggest that the operating contractors that actually do demolition work be contacted by NRC and asked to provide current and realistic information in this subject.

10. Turning to the draft GEIS discussion of the construction cost of a mill. Appendix K-4 sets forth a total cost of $7.1 million for mill equipment. It is not clear whether this figure ($7.1 million) is intended to represent the total cost of a mill. If it is, it is seriously deficient as current engineering estimates for a complete mill with a 2,000 tons per day capacity vary from $25-45 million.

11. The draft GEIS does not consider the administrative and legal costs that are directly attributable to the proposed regulatory program. A recent Bureau of Mines Report on mining costs indicates that the cost of preparing impact statements may be substantial. One company has just spent over $1 million preparing various reports in an attempt to get a license renewed. Another company has to date, spent in excess of $1 million trying to get an agreement with NRC on a tailings disposal plan. They have estimated that their total regulatory costs before they finally obtain a license will be $1.5-2 million. AMC believes that a minimum cost of $2 million should be assumed for processing license applicatons through the administrative hearing stage.

12. An even more significant regulatory cost is the cost of interest. The largest single cost in constructing a nuclear power plant today is the interest cost during construction of "IDC". This is a larger cost than either labor or materials. In many cases a substantial portion of the IDC cost is directly attributable to regulation (capital costs and regulatory delays). One uranium developer has estimated his IDC cost to be over $50,000/day. If the IDC cost is calculated on the basis of the $65,000,000 discussed above, the IDC cost alone would probably be more than the GEIS <u>total</u> cost estimate of $9,000,000. A thorough presentation of costs must include IDC costs.

13. Where an open pit mine is used for tailings disposal, the cost of backfilling and restoration is not included as a cost of tailings disposal since, according to the draft GEIS, it would be required anyway by some state laws. Reclamation requirements vary from state to state and, in any event, complete backfilling is not normally required.

14. In calculating the cost of providing cover, the draft GEIS fails to take into account the cost of fill required to stabilize the slimes sufficiently to permit heavy equipment operation. This could add an additional five feet to the cover requirements. The period needed for tailings to dry prior to reclamation was not taken into account in estimating the duration of bonding (an additional 5 to 10 years). This will increase the cost of bonding accordingly.

15. The costs presented in the draft GEIS are in 1978 dollars. Although the draft GEIS notes that costs are likely to escalate

in the future (Appendix K-4 of draft GEIS at K-11), no adjustments for inflation are provided, particularly increases in the cost of energy. A recent Bureau of Mines report forecasts approximately an 11 percent annual increase in costs. One company is currently experiencing escalation rates of about 14 percent. The draft GEIS fails to take into account costs attributed to inflation which will have a significant impact on the cost of constructing the new mills and tailings disposal systems projected in the draft GEIS.

16. Some important impacts or costs, e.g. increased energy consumption, were completely ignored; others, such as effects on productivity received only nominal attention. Attached as Exhibit B are calculations of the amount of energy required to place 10 feet of cover on a uranium tailings pile.

17. On page K-29, the draft GEIS hypothesizes a situation where a cover operation merely involves "pushing" overburden over the tailings, thus reducing cost for excavation, hauling, spreading, and compacting. This is not a realistic hypothetical -- AMC is not aware of any tailings site where this is done. At a minimum, the overburden would have to be hauled and stored a mile or two from the tailings site.

18. No contingency costs, which would normally be about 15-20 percent of the quoted figures, were added to the draft GEIS cost figures (Draft GEIS at 11-1).

19. Future EPA regulations could be different than those assumed in the draft GEIS. (Draft GEIS at 13-5). Costs incurred

to comply with new EPA regulations, although a realistic possibility, were not taken into account. Additional costs could be incurred as a result of more stringent EPA regulations.

20. AMC requests that the NRC staff review its cost figures for mill decommissioning. Actual costs incurred by mill operators vary significantly from the cost data in the draft GEIS.

In addition, AMC offers the following miscellaneous comments on costs discussed in other sections of the draft GEIS:

Chapter 11.

1. Page 11-6, Paragraph 11.2.7. Alternative 6 text: Table 11.8.

Estimated Incremental Costs for Alternative 6
(thousands of 1978 dollars)

Total 4150/6300

COMMENT: Estimated costs developed by one operator indicate the total cost in Table 11.8 is underestimated by approximately a factor of 3.

2. Page 11-7, Paragraph 11.2.8. Alternative 7 text: "At this point, the sands and slimes would be separated. The sands would be washed with clean water, partially dried, and deposited in the unlined mine pit."

COMMENT: Washing sands with clean water after separation from slimes results in contamination of water requiring further treatment or evaporation. In addition, experience indicates five stage washing will not remove significant amounts of radium.

3. Page 11-7, Table 11.10. Annual Operating Costs for Alternative 7 and 8. (thousands of 1978 dollars)

COMMENT: In Table 11.10, no provision is made for the annual operating costs for neutralization. Page K-6 of this appendix indicates this would amount to approximately \$27/MT, adding approximately \$217,000 to the total annual cost shown.

APPENDIX K

4. Page K-2, Paragraph 1.2. Windbreak text: "For this alternative, a 3.7-m high sheet metal or wooden fence would be erected on three sides of the 8-ha ore storage pad, each side being 290m long. The cost is linearly scaled and escalated from Reference 2 for a total of \$52,000 for either type of fence."

COMMENT: A 12 foot high windbreak would have little effect on wind blowing across the top of a stockpile 20 feet high. To be effective the fence would have to be 40-50 feet high and such a fence would cost on the order of \$1 million. Significant maintenance costs would be incurred during the life of the fence and during the winter it would act as a snow fence causing snow accumulation problems on the ore pad.

APPENDIX K-2

5. Page K-6, Paragraph 3. Fossil-Fueled Evaporators text: "The capital costs of evaporators and associated equipment with an evaporation capacity of 4.6×10^5 m^3 of water per year are estimated as \$1.45 million (1978 costs). With a 70% thermal efficiency, 90,000 MT of coal per year would be required, at a cost of \$2.55 million."

COMMENT: The relatively low capital cost estimate for the evaporators and associated equipment suggest that it corresponds to a unit constructed of iron. When considering the corrosion rate which could reasonably be anticipated in this service, the use of iron will not be the most economical material. Further, most acid mills have a high concentration of sulfate and sufficient amounts of calcium so that calcium sulfate scale would be a continuous operating problem. Accordingly, it seems likely that such a system should cost well in excess of the $1.45 million.

6. Page K-11, Paragraph 3. text: "Many mill operators also are engaged in mining activities and thus possess the equipment and expertise to perform all earthworking tasks; furthermore, these operations would be more readily phased in with other mining and milling activities in this circumstance, regardless of tailings disposal requirements."

COMMENT: The statement relative to mill operators engaged in mining activities possessing the equipment and expertise to perform earth working and phasing these reclamation tasks in with "other mining and milling activities" is not applicable. Because of the drying time requirement, in many cases reclamation activities will occur years after the termination of all mining and milling activities. Expectations that a company would utilize trained miners for ordinary earthwork are unrealistic.

In conclusion, the improper approach and the examples of inaccuracies and omissions discussed above, make it clear that the cost estimates contained in the draft GEIS are not sufficiently accurate for use in any meaningful cost effectiveness analysis. Therefore, it is our recommendation that the cost data be redone in a revised draft GEIS with particular emphasis on the secondary costs that will be involved such as the cost for acquiring dirt, the cost of rehabilitating any borrow areas, IDC costs, etc.

Exhibit A

Tailings Disposal Costs	NRC Estimated Cost	AMC Member Company Actual & Estimated Cost
a. Excavate, load, haul (≤ Km) and deposit.	$\$0.97/m^3$	$1.40
b. Truck, Transport.	$\$0.08/m^3$-Km	$0.40
c. Spreading and Compacting to approximately 98% proctor density, such as for the clay core of a tailings dam, or for implacement of a clay liner.	$\$0.33/m^3$	$0.50
d. Spreading and compacting such as backfilling a pit.	$\$0.33/m^3$	$0.30
e. Compacting soil already in place such as in preparation for a clay or hypalon liner.	$1,750/ha	$3,500
f. Installation of clay liner. (1 meter thick)	$\$1.30/m^2$	$1.50
g. Installation of hypalon liner (30 mil) includes preparation cost for base other than compacting shown as item "e" above.	$\$4.00/m^2$	$11.00
h. Installation of PVC liner (30 mil) includes preparation cost for base other than compacting shown as item "e" above.	$\$3.00/m^2$	$4.60
i. Chemical Stabilization of haul roads.	$1,000/ha	———
j. Resurfacing and Revegetation grading, implacement of 0.15 m of top soil, mulching and seeding.	$2,500/ha	$10,000
Mill Construction Costs:		
Estimate of capital costs for a grass roots uranium mill:	$7.1 million	$25-45mm

Exhibit B

Comment: The amount of energy required to add ten additional feet of cover on a uranium tailings pile is equivalent to:

(1) Driving the family car 5,649,151 miles at 17 miles per gallon - or -

(2) Driving an 18-wheel over-the-highway truck 1,170,080 miles at 4 miles per gallon - or -

(3) Supplying the average New Mexico home with 24,292.6 months of electricity at 501 kw/month.

Calculations:

Factors

1 acre = 4,840 yd.^{3} (1)

5 feet = 1.67 yds.

1 BTU = 2.930 x 10^{-4} kilowatt hours (1)

BTU per gallon of diesel = 142,000 (2)

BTU per gallon of gasoline = 125,000 (2)

Assumptions

Surface area of tailings pond = 240 acres

Average depth of cover = 10 feet

One-way haul distance of soil = 1 mile

Equipment

Type = CAT 637D

Fuel consumption (medium usage conditions) =

19 gallons per hour.

Equipment (cont'd)

Cycle time, one mile, one way

Loaded = 2.60 minutes

Empty = 2.10 minutes

Load Time = 0.75 minute

Dump time = 0.50 minute

Total, cycle 5.95 minutes

Operating minutes per hour = 50

Capacity = 30 yd.^{3}

Calculations

Volume = (240 acres x 4,840 yd.^{2} per acre) x 3.34 yd. depth = 3,879,744 yd.^{3}

Trips per hour:

= 50 minutes worked per hour ÷ 5.95 minutes per trip = 8.40 trips per hour.

Yd.^{3} moved per hour:

= 8.40 trips per hour x 30 yd.^{3} per trip = 252.0 yd.^{3} per hour.

Total operating hours required:

= 3,879,744 yd.^{3} ÷ 252.0 yd.^{3} per hour = 15,395.8 hours.

Fuel required:

= 15,395.8 hours x 19 gallons per hour = 292,520.2 gallons.

Equivalence

BTU's = 292,520.2 gallons of diesel x 142,000

BTU/gallon = 41,537,868,000

Gallons of gas:

= 41,537,868,000 BTU ÷ 125,000 BTU/gal. of gas

= 332,303.

Kilowatt hours:

= 41,537,868,000 BTU x 2.930 x 10^{-4} kilowatt/BTU

= 12,170,595.3.

OR -

(1) Drive the family car 5,649,151 miles at 17 miles per gallon.

(2) Drive a over-the-highway truck 1,170,080 miles at 4 miles per gallon.

(3) Supply the average home in New Mexico with 24,292.6 months on electrical power at 501 kw/month.

References

(1) Burington, R. S. Handbook of Mathematical Tables and Formulas, Bureau of Ordinance, U. S. Navy.

(2) Peele, Robert. Mining Engineer's Handbook, John Wiley & Sons, Inc., p. 40-39.

(3) Caterpillar Performance Handbook, Eighth Edition. Caterpillar Tractor Company, Peoria, IL, pp. 11-40, 11-41, 26-21.

(4) Telephone conversation: R. M. Robb and Public Service Company of New Mexico, July 7, 1979, "average home power consumption."

Part III

D. Decommissioning Considerations

D. DECOMMISSIONING CONSIDERATIONS

SUMMARY

The requirements of the Target Criteria, issued in Regulatory Guide form (Appendix J, "Interim Land Cleanup Criteria for Decommissioning Uranium Mill Sites") will be, if implemented, so strict that compliance will be difficult if not impossible. For all mills, emphasis should be placed on complying with the Alternative or Upper Limit Criteria coupled with the application of ALARA. The decommissioning costs set forth in the draft GEIS are low by at least a factor of three.

COMMENTS

The following comments are submitted with respect to the subject of decommissioning:

1. Appendix J, Interim Land Cleanup Criteria for Decommissioning Uranium Mill Sites

A. Although NRC stipulates that the Target Criteria not only should account for natural background concentrations of radionuclides in soil, but also should be distinguishable from these natural background levels without incurring highly significant costs associated with sampling and analyses, NRC has developed Target Criteria that are so technically difficult to comply with as to be cost prohibitive. For example, terrestrial absorbed dose rates in air in Denver, Colorado range from 8-16 micro-R per hour. (NCRP 45, 1975). Since ranges of this order occur throughout the United States, it would be extremely difficult, if not impossible, to differentiate between levels which are 5 micro-R per hour above background and natural variations in background.

Similarly, while Appendix J/E (page J-13) depicts radium-226 soil concentrations in western United States milling regions as varying between 0.2 and 3.4 pCi/g, background concentrations ranging from 1 to 2 orders of magnitude higher are not uncommon. Considering the relatively large area (here assumed to include the complete restricted area, average acreage of 750 acres) encompassed by the milling complex, it would thus be problematical to obtain representative samples that could adequately differentiate between radium-226 at infinite thickness from variations in natural background radium-226 concentrations. In addition, because of the limitations of present analytical techniques, the significance of any suite of analytical values representing natural radium concentrations in soils will include statistical errors which may readily exceed 50% of the designated values.

B. The radon-222 flux (above background) at the soil/air interface has been linked not only to a soil concentration of radium-226 of infinite thickness, but also to a working level concentration in potential structures built on contaminated land. Where such flux has been determined, based on conversions from radium in soil to radon flux to working levels concentrations in homes, the Target Criterion of 0.006 Wl (Table 2, page J-8) is not reproducible from the figure presented in Appendix J/A (pages J-8 and J-9). More specifically, in the Table entitled "Potential Exposures from Radon Inside Structures on Contaminated Land" (Appendix J/A, page J-9, Note 3), working levels derived on a radium-226 soil concentration of 3 pCi/g are not based on the range of values for B and for λ as referenced in footnote 3a (Appendix J/A, page J-9). These restrictions on values used for parameters B and λ necessarily bias the values derived for radon progeny concentrations.

C. The value of 0.006 WL as a Target Criterion (Table 2, page J-8) vis-a-vis "Other Existing Criteria or Guidance" is arbitrarily restrictive. It is not apparent to what extent NRC has addressed both the costs and the corresponding benefits associated with complying with the Target Criteria in lieu of complying with the Alternative or Upper Limit Criteria (where emphasis is placed on implementation of the ALARA philosophy).

Rather than merely presenting a set of criteria, the draft GEIS should include a comparison of alternative criteria, together with supporting scientific data for each. Once suitable alternatives are analyzed and appropriate target and upper levels determined, the upper limit criteria should apply to each site. The target criteria should no longer represent an objective. Instead, it should only represent a level below which no further treatment is required. The actual criteria should be developed on a site-specific basis setting levels as low as reasonably achievable, but somewhere between the upper limit and target criteria.

2. Page 24, Executive Summary, Section 6.5, Implementation of Proposed Requirements at Existing Sites

Text:

"In addition to constraints on alternative tailings disposal methods resulting from existence of very large volumes at existing sites. . ., there will be a greater problem in paying for tailings disposal at these sites because disposal costs were not incorporated in the price of the product as the tailings were being generated. Therefore, future operations at such sites will have to provide for disposal for both newly generated and existing tailings. This matter must be considered in site-specific decisions."

Comment:

A similar argument should be applied to existing milling operations. Full recognition should be given to the fact that existing mills have operated in accordance with a different set of standards than are being proposed. As a result, the magnitude of the decommissioning costs to be incurred by complying with the proposed criteria were never included in the contract price of the yellowcake product. Therefore, rather than mandating the existing mills to comply with decommissioning standards that use "original background levels" as a reference, the Alternative or Upper Limit Criteria for decommissioning should be related to background conditions as such conditions exist on the date regulations governing decommissioning of milling sites become effective. Such a decision not only recognizes that decommissioning costs can only be borne by prospective sales, but also accounts for the paucity of data regarding natural background levels. A corresponding precedent has been established by EPA in the 40 CFR 190 Standard, which relates to background conditions existing on the effective date of the Standard.

3. Page 8-27, Section 8.5, Text:

"Finally, all excavated areas would be backfilled and graded, topsoils would be added whenever necessary, and the areas would be revegetated."

Comment:

It is not apparent to what extent the costs for backfilling, grading, adding topsoil when necessary, and revegetating have been included in Table 11.13, Summary of Cost Estimates for Decommissioning (1978 dollars). More appropriate cost estimates for decommissioning a milling site (excluding tailings pond) would include the following:

(1) Building, foundation and machinery removal (1979 dollars): 6.5% of total capital cost of mill.

(a) Estimated capital costs of mills (including equipment):

1000 tpd:	$17,000/daily ton
2000 tpd: ≈	$13,000/daily ton
3000+tpd:	$11,000/daily ton

(Reference: Dravo Engineering, Denver, CO, personal communication, June 7, 1979)

Thus, for an estimated $30 million capital cost to build a mill, the costs to tear down buildings and foundations and to remove equipment to the tailings pond and to reclaim the land surfaces would be about 1.95 million dollars.	$1,950,000

(b) Heavily contaminated area (20 acres x 3 feet)

(i)	Removal of 100,000 cubic yards of dirt at $1.00 per cu. yd.	$ 100,000
(ii)	Replacement of 100,000 cubic yards at $3.00 per cu. yd.	300,000
(iii)	Revegetate 20 acres $5,000 per acre . .	100,000
		$ 500,000

(c) Lightly contaminated area (300 acres x 6 inches)

(i)	Removal of 242,000 cu. yd. $1.00 per cu. yd.	$ 242,000
(ii)	Replacement of 242,000 cu. yd. at $3.00 per cu. yd. (optional)	726,000*
(iii)	Reclaim 300 acres at $5,000 per acre. .	1,500,000
		$1,743,000 - $2,468,000
	Sub-Total	$4,192,000 - $4,918,000

* Where replacement soils are removed from a borrow pit, it is more difficult to determine the costs associated with reclaiming the borrow pit. See testimony of Gordon Swanby on behalf of AMC at Albuquerque, New Mexico, hearings on the draft GEIS, Part III, Item J.

(2)	Engineering, 6% of Sub-Total	$ 251,520 - $ 295,080
(3)	Contingency, 15% of Sub-Total	$ 628,000 - $ 737,700
	TOTAL	$5,072,320 - $5,950,780

Part III

E. Financial Responsibility -- Alternatives

E. FINANCIAL RESPONSIBILITY - ALTERNATIVES

SUMMARY

The Draft Generic Environmental Impact Statement approaches financial aspects of uranium mill decommissioning and tailings management as two separate subjects. These two concepts are: (1) short-term financial surety "to insure the mill operator undertakes the required decommissioning activities", and (2) long-term funding "to finance any ongoing care and monitoring after termination of decommissioning and license".

The staff has utilized extensively other studies conducted on financial alternatives for stabilization, reclamation, and long-term monitoring and maintenance of uranium mill tailings piles. Since these studies were conducted, the reluctance of insurance companies to obligate themselves as a surety for an indefinite period of time and excessive costs connected with obtaining performance bonds have created serious difficulties for the licensee.

In addition, the staff gave very brief consideration to the issue of "commingled tailings", referring to UMTCA assigning primary responsibility to the Department of Energy for carrying out remedial actions. The United States General Accounting Office recommended to Congress that it provide assistance to active mill owners to share in the cost of cleanup that portion of the mill's tailings that were generated under Federal contracts."[1]

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[1] Controller General of the United States report to the Honorable Mark O. Hatfield, Committee on Energy and Natural Resources.

In the financial formula, it is recommended that the staff include reference to Congressional liability for commingled tailings and that in the bonding requirements, licensees should be in a position to reduce their costs for decommissioning and reclamation of mill tailings generated under Federal contracts and for decommissioning and reclamation of such millsites. We believe the staff should include similar provisions for structuring surety and bonding arrangements.

COMMENTS

1. Page 14-10, Text:

A. Specifically, the staff,NRC, proposes that the regulation: (Page 14-10)

   1. require that a surety be provided;
   2. require that the amount of the surety be determined on the basis of cost estimates in the approved plan for site decommissioning and tailings disposal; costs should be those for hiring an independent contractor to perform these activities. The amount of the surety should also include the long-term funding charge since this will not be paid to the ultimate custodian until termination of the license;
   3. allow flexibility regarding the specific surety mechanism employed, stating that:
      - cash deposits
      - surety bonds
      - certificates of deposit
      - deposits of government securities, and
      - letters of credit

would be acceptable on a generic basis, and other surety mechanisms would be evaluated on a case-by-case basis, for acceptabliity.

4. Stipulate those factors that must be considered in setting up the surety arrangement:

    - inflation;
    - noncancellable nature of the mechanism (i.e., the term of the surety must be open-ended -- it must remain in effect until the regulatory agency releases it, on satisfactory completion of decommissioning and reclamation); and
    - adjustment provision that ties the review for surety adequacy in with the license renewal period, not to exceed five years. The amount of the surety should decrease in accordance with decommissioning and reclamation that has been performed. This will yield a surety that is at least sufficient at all times to cover the costs of decommissioning and reclamation of the areas that are expected to be disturbed, before the next license renewal.

AMC Recommends that the above section on Short-Term Financial Surety be rewritten as follows:

A. During operations, the licensee shall show its financial ability to comply with all material license requirements by any one of the following methods:

1. surety bond(s);
2. letters or lines of credit;
3. self-insurance;
4. guarantee by a state governmental agency, local governmental agency or other third party which could qualify for self-insurance.
5. Other methods, acceptable to NRC[2] or
6. any combination of the method specified 1 through 5.

The licensee may change its method or methods of showing its financial ability on each license renewal date, prior to issuance of such renewed license.

B. Immediately prior to the cessation of operation of a facility for which a materials license has been issued, or before a licensed active waste-retention system becomes an inactive waste-retention system, NRC may require the licensee to show its financial ability to comply with all remaining

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[2] Or whatever agency is selected to administer the surety arrangements.

material license requirements by any one of the following methods:

1. surety bond(s);
2. letters or lines of credit;
3. self-insurance;
4. guarantee by a state governmental agency, local governmental agency or other third party which could qualify for self-insurance.
5. Other methods, acceptable to NRC, or
6. any combination of the methods specified in B 1 through 5.

C. Proof of financial ability in accordance with these requirements shall be furnished to NRC prior to the issuance of new or renewed licenses. Financial ability no longer need be provided after demonstration by the licensee that the conditions of the materials license have been satisfied.

D. The standard applied in determining the amount of financial ability shall be the estimated cost to perform the engineering plan for the stabilization of waste-retention systems and other decommissioning activities approved in the materials license less costs for decommissioning and reclamation of mill tailings generated under Federal contracts. This amount shall be based on:

1. The estimated cost at the end of the renewed materials license period to execute the engineering plan stated in the license for the stabilization of waste-retention systems and other decommissioning activities.

2. The quality of tailings projected to exist at the end of the renewed materials license period, less those tailings generated under Federal contracts, to which the engineering plan stated in the materials license is applicable.

3. The additional estimated costs (limited to 10% of the costs estimated under subsection D.1.) which may arise from contracting requirements or the need to bring personnel and equipment to the site to perform the engineering plan of paragraph D.1. above.

The amount shall be adjusted at each materials license renewal period and consequently will recognize any increase or decrease in requirements resulting from inflation, changes in engineering plans, stabilization in conjunction with operations, and any other conditions affecting the costs to fulfill the engineering plan described in the renewed materials license.

During the stabilization period of an inactive waste retention system for which a materials license has been issued or when other decommissioning is being performed on a facility for which a specific license has been issued, the amount of financial ability that must be established must be reduced annually to reflect portions of the engineering plan performed during the current year.

E. The methods for showing financial ability are defined as follows:

1. Surety bond means an indemnity agreement in a sum certain payable to NRC executed by the licensee which is supported by the performance guarantee of a corporation licensed to do business as a surety. Terms and conditions of such surety bonds shall be the normal terms and conditions of the surety industry and shall be for the period of each renewed materials license.

2. Letters or lines of credit means issuance of a letter of credit by a recognized bank or financial institution that commits such institution to pay the beneficiary, NRC, when the letter of credit comes due. The letter of credit comes due upon the licensee's failure to complete all materials license requirements.

3. Self-insurance means showing financial responsibility and performance capability based on the legal obligations of the materials license and the continuing existence of unobligated working capital and net worth, (including assets which may be liquidated or estimates of cash flow) sufficient to cover requirements of D.

    a. Qualifications for self-insurance will be supported by a copy of the licensee's current balance sheet, income statement, statement of changes in financial position that are certified by an independent Certified Public Accountant and must be accompanied by either:

        i. An additional statement confirming both that the licensee's current assets exceed the current liabilities by the amount of financial assurances determined to be necessary under D., and that the licnesee's net worth, plus any self-insurance reserve which may be established for this purpose, also exceeds this amount, or

ii. A statement, based on an analysis of the licensee's financial position, which shows that sufficient assets which may be liquidated or cash flow, are or will be available to provide the funds necessary to retire a claim for the amount required by D. without the licensee becoming insolvent.

b. If the licensee files a Securities and Exchange Commission Form 10-K report, a copy of the licensee's most recent 10-K report shall be filed with NRC within 120 days after the end of the fiscal year to which it relates, in addition to filing the most recent 10-K report with the initial application.

c. Each licensee shall file annually with NRC copies of documents required under subsection E.3.a. within 120 days after the close of the licensee's fiscal accounting period. If a licensee files a 10-K report with NRC under subsection E.3.b. which contains some of the financial statements required in subsection E.3.a., a separate filing of those specific statements need not be made.

d. In the cases where the licensee is a subsidiary or partnership, the owner(s) may be the guarantor for purposes of these regulations. In such cases, the guarantor shall be subject to and shall fully comply with all of the self-insurance provisions of this subparagraph E.3.

4. Other methods:
The NRC will accept alternative evidence of financial responsibility if it establishes an equivalent degree of financial responsibility for the purposes of this regulation.

F. No bond, letter of credit, or other secured interest of any kind provided by the licensee to fulfill the requirements of this section shall become payable until a final determination has been made in accordance with these procedures that the licensee has failed to complete the requirements of its license.

2. Page 27, Summary, Text:

Long-term funding refers to the financing of any monitoring at mill tailings sites after termination of the mill operator's decommissioning responsibilities and license. The staff has concluded that it would be prudent to continue monitoring and exercising land use controls at disposal sites, and the land ownership arrangement specified in the recent enactment assures that this kind of control is provided. The purpose of this surveillance would be to confirm that no unexpected erosion was occurring and that there were no disruptive human activities at a site. Therefore, the primary component of the surveillance would be periodic visual inspection of each site. The staff proposed the following be done with regard to the issue of long-term funding: (Section 14.3.1)

- Funds should be provided by each mill operator to cover the costs of long-term monitoring.
- A charge of $250,000 (1978 dollars) per site should be levied on mill operators, before termination of a license. The charge would be paid to the Federal Government unless the state in which a mill is located chooses to have this responsibility. In any event, the sum for long-term monitoring should be paid to whichever government body is going to be the ultimate custodian of the site.
- If the long-term monitoring charge is paid to the Federal government, it should be deposited in the general treasury funds of the United States, as opposed to a special earmarked fund that might be established. In the situation where a state opts to have custody of a site, it will also be responsible for fund management. Therefore, if a State wishes to deposit long-term surveillance funds in an earmarked account, rather than seek an annual or biannual appropriation from the State legislature for this purpose, it would be free to do so.
- If monitoring requirements at a particular site are determined, on the basis of a site-specific evaluation, to be significantly greater than those assumed here (annual visual inspection with some limited groundwater monitoring possible), variance in funding requirements should be arranged.
- The amount paid by operators for long-term funding should be adjusted to recognize inflation. The inflation rate to be used is that indicated by the change in the Consumer Price Index, which is published regularly by the U.S. Department of Labor, Bureau of Labor Statistics.

AMC Recommends that the above section on Long-Term Funding be rewritten as follows:

1. Funds should be provided by each mill operator to cover the cost of long-term monitoring.

2. A one-time charge of $250,000 or less (1978 dollars) per site should be levied on mill operators before the termination of the license. If monitoring requirements at a particular site are determined to be significantly less, reduced funding requirements will be arranged. The sum will be paid into the governmental body which has ultimate custody of the site.

3. The governmental body, the ultimate custodian, should deposit long-term funding in an earmarked account for each licensee. The money should be reinvested and the interest generated should be returned to the earmarked account.

4. Since costs associated with Passive Monitoring Mode are expected to be relatively small, there should not be any need or justification for additional monies to be charged to the licensee in excess of $250,000.

5. Proper investment of the earmarked account should preclude the necessity for adjusting the amount paid by operators due to inflation rate.

3. Page 14-6, Text:

Some background information is necessary to develop some appreciation for the costs of obtaining such a surety bond. The intent of this computation is only to give an order-of-magnitude estimate of the out-of-pocket costs incurred by the mill operator, in addition to the actual costs for performing reclamation at a typical mill. The active lifetime of the typical plant assumed in this study is fifteen years. During this period, the plant would process 11 million tons of ore and produce 21,900 tons of yellowcake. Assuming that the surety bond would be obtained in the mill's first year of operation and continue through five years after the active plant lifetime, the bond would be an out-of-pocket cost item for a total of 20 years. (emphasis added)

4. Page 14-3, Text:

In any event, as a counsequence, the time period is expected to span several years, primarily to allow time for the tailings to dry sufficiently to permit the use of heavy earth-moving equipment on them. The period of drying will vary, depending on site specific circumstances, but could last as long as ten years. (Emphasis added.)

Comments:

The staff did not consider the drying-out period in the calculation of 20 years for the total bonding period. It would appear more reasonable to assume bonding requirements to be in the area of 30 to 40 years. Since the drying-out period is in the decommissioning and reclamation phase, a licensee will be required to bond for an additional ten years, beyond the time period selected by the staff. This further substantiates the need for flexibility regarding methods, timing, and amounts of surety arrangements.

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PART III

F. OTHER MATTERS

1. Other Concerns with the Draft GEIS
2. AMC Comments on State Comments

1545 134

PART III

F. 1. OTHER CONCERNS WITH DRAFT GEIS

F. 1. OTHER CONCERNS WITH DRAFT GEIS

1. Summary, Section 3.5, Text

". . . the most severe potential accidents are those involving shipment of yellowcake . . ."

Page 7-8, Section 7.1.5.1, Text

". . . it is possible that in the future, yellowcake will be transported as a slurry to the conversion facility" and "it is expected that the consequences (of a slurry shipment) would be considerably lower than those estimated for the shipment of any concentrate . . ."

Comment:

Whereas NRC may believe there is some basis for asserting that yellowcake transport accidents are the most severe potential accidents, the probability of such occurrences as well as the orders of magnitude of projected impacts should be presented to support this assertion. Considering the suite of possible accidents, both radiological and non-radiological, which could occur in conjunction with milling operations, it appears likely that accidents of another nature would produce more far-reaching effects than a transportation accident. Furthermore, while it is "expected" by NRC that the consequences of a slurry transport accident would be less severe than the consequences of a yellowcake transport accident, NRC has not demonstrated this. Therefore, the present analysis of potential accidents should not serve as a basis for converting from yellowcake transport to slurry transport.

2. Page 11-2, Table 11.1, Costs of Selected Alternatives, Text

"Costs are difficult to estimate for this alternative. Capital costs would be incurred in purchasing containers for the shipment of wet cake, and operating costs would appear as shipping costs. The staff currently has no information on which to base estimates of these costs."

Comment:

In contrast with the above statement, on page K-3 of the draft GEIS, the shipment of wet slurry is suggested as a replacement for extensive drying systems for dust control and conclusions are reached with regard to the fiscal tradeoff for this transport alternative. In addition, NRC's cost estimates for slurry transport appear applicable only to net mills. Because of the significant costs involved, retrofitting existing mills and converting facilities to handle slurry could not be justified any time in the near future.

3. Page 11-3, Table 11.3, Estimated Costs for Base Case and Alternative 1, Text

"Base Case		
	Total	$ 320,000
Alternative 1		
	Total	$5,320,000"

Comment:

The estimated cost of alternative 1 shown in Table 11.3 is underestimated by approximately 50% according to an estimate made by one operator in 1977 for its mill in Wyoming.

4. Page 24, Section 6.6, Heap Leaching and Small Processing Sites

Comment:

If unconventional milling techniques are to be regulated by the NRC, then regulations related to such techniques should not be promulgated until an in-depth study of all issues concerned has been conducted. This is especially true for in-situ solution mining of uranium where many of the activities associated with conventional milling are not present, e.g., haul rods, ore pads, ore crushing facilities and tailings ponds. Therefore, the same tailings management and disposal criteria proposed for conventional mills should not be indiscriminately applied to unconventional milling techniques.

PART III

F.2. AMC COMMENTS ON STATE COMMENTS

F.2. AMC COMMENTS ON WRITTEN COMMENTS SUBMITTED BY THE STATES OF COLORADO AND NEW MEXICO

The written comments on the draft GEIS submitted by the Colorado Division of Mines on June 13, 1979, through the State Clearinghouse and the Colorado Division of Planning were reviewed by AMC. The comments of the State of New Mexico Radiation Protection Section were also reviewed. The AMC agrees with the following points made by each of these state agencies.

State of Colorado:

* * * * *

> "We agree with the statement that individual, site-specific environmental assessments are necessary and should be thorough. Rational engineering, efficient milling methods for long-term investment and clever design for tailings impoundment should allow compliance with operational requirements without undue economic burden on the industry."

* * * * *

> "Decontaminating a mill site to background radiation levels is impractical based on experience. It will require considerable excavation and burial with clean earth cover. It does not practically consider the ultimate land use and benefit to be derived for these sites, which adjoin tailings disposal locations."

* * * * *

> "We feel strongly the premature death calculations for the North American continent extending to the year 3000 are preposterous. It presumes no improvement over past milling practices and no reuse of uranium fuel."

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State of New Mexico: General Comments

* * * * *

"3. Some indication should be given to the anticipated errors or ranges for the various doses, concentrations and health effects calculated. What kind of precision and accuracy is expected of the UDAD code? Of the source term estimates? Of the atmospheric radionuclide concentrations? Of the dose conversion factors? Of the deposition velocities? For example, on page 6-74, 72 premature deaths were predicted from continental environmental dose commitments from uranium milling. What is the range of this number taking all uncertainties into account? In order to have some feeling for the firmness of these estimates, their ranges should be calculated or some estimate of their variability expressed. In general, there is an overly detailed presentation of results that most likely cannot be justified by the precision and completeness of the associated data base."

* * * * *

"7. The following comments were generated by Water Pollution Control Section (WPCS) staff, of the New Mexico Environmental Improvement Division and to a certain extent reflect comments previously submitted to NRC in a December 11, 1978, memorandum from Joseph A. Pierce, Chief, WPCS to Al Topp of the Radiation Protection Section. The discussions relating to ground water and ground water protection do not place this resource in proper perspective from a tailings management point of view. The most significant deficiencies in the ground water discussions may be summarized as follows:

a. While the document generally recognizes the importance of protecting ground water quality, there is no discussion of ground water flow systems as contaminant transport pathways. This is a fundamental point, the importance of which must be appreciated if adequate ground water protection is to be insured. Knowledge of where a tailings site lies with respect to local and regional ground water flow systems, coupled with knowledge of where present or future ground water withdrawal points are or will be located, is essential to any ground water protection effort.

Ground water must be thought of as a contaminant transport pathway not unlike wind is viewed, with attenuation mechanisms and time/spacial factors obviously being quite different.

b. The GEIS offers no discussion of the importance of site selection as related to ground water protection. NRC staff seem to feel that the only way to mitigate adverse water quality impacts of tailings disposal areas is through alternate disposal schemes incorporating elaborate and costly engineering controls (see pp. 19, 23, 6-12, 8-18 and 12-20). This is simply not true, especially with respect to ground water protection which can, in many cases, be most effectively insured through judicious site selection to take advantage of favorable hydrogeologic conditions."

<u>State of New Mexico</u>: Specific Comments

"<u>Forward</u>

1. Page ii, 1st two sentences: Revising NRC regulations based on the conclusions of this <u>draft</u> statement does not seem to be a prudent course of action until comments have been received, evaluated, and a final document issued. These sentences appear to be telling reviewers that NRC has already determined what is necessary and comments on the draft are incidental.

2. Page ii, 3rd sentence from bottom: The project should not be considered as complete until the final document is issued."

* * * * *

"<u>Summary</u>

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"7. Page 31, References: Five of the eleven references which are vital to a technical evaluation of the GEIS and the NRC regulatory proposals are identified as 'in preparation.' Thus, an adequate evaluation cannot be accomplished until these are available."

* * * * *

"Section 3

1. Page 3 (3.1), line 7: While the base case in theory represents past milling practices, the obvious assumption by the reader is that this is the actual situation today. The base case is representative of the licensing practice of NRC's predecessor, AEC."

* * * * *

"5. Page 9 (3.5): The last paragraph states that worst-case accidents involving shipment of yellowcake in a populated area are expected to cause total exposures as much as 10 times that from a single mill's annual operation. However, NUREG-0525 (pages 9 and 10) states: 'The low concentration of radioactivity conceptually renders the material (yellowcake) "inherently safe", considering radiological effects of the material, because it is highly unlikely, under any circumstances arising in the transportation of these materials, including accidents in which the material is released to the environment, that a person could take in enough material to produce a significant radiological effect.' The GEIS (NUREG-0511) and NUREG-0535 appear to be in conflict regarding the hazard potential due to yellowcake."

* * * * *

"Section 6

1. This section and supporting appendices, do not made sufficiently clear that the radiological impact calculations, particularly the matter of conversion from exposure dose to absorbed dose and health effects, are highly uncertain and speculative. The uncertainties in the input data, computations, and effects data are so great that to compare 72 premature deaths from mills with 109 premature deaths from mines is nonsense. It would still be nonsense even if one talked about 70 and 110 which would at least acknowledge the uncertain nature of the numbers. The entire presentation, and poor use of significant digits, is misleading and, unfortunately, perhaps the most important factor upon which all of the GEIS recommendations, conclusions, and proposed regulations are based. The best, and most meaningful, use of dose calculations is to compare and rank alternatives and to determine compliance with standards. The latter will, in the long run, be based on judgment heavily

weighted by conservatism due to the acknowledged lack of hard data on health effects. As it is written the GEIS appears to attach far more significance to the validity of the computations than is warranted."

* * * * *

"<u>Appendix G</u>

1. Page G-5, last sentence: It is assumed that 5% of the thorium activity is in the yellowcake for an acid leach mill. However, recent data from both Argonne National Laboratory and the Environmental Protection Agency indicate that the thorium activity is much lower, around .2%."

PART III

G. DERIVATION OF THE PROPOSED REGULATIONS AND LICENSING CRITERIA FROM NRC PERFORMANCE OBJECTIVES, BRANCH POSITIONS, AND REGULATORY GUIDES

G. DERIVATION OF THE PROPOSED REGULATIONS AND LICENSING CRITERIA FROM NRC PERFORMANCE OBJECTIVES, BRANCH POSITIONS, AND REGULATORY GUIDES

BACKGROUND OF AEC AND NRC LICENSING PROCESS

The licensing process for uranium mills had its beginning under the Atomic Energy Commission. In 1973, the AEC published Regulatory Guide 3.5, "Guide to the Contents of Applications for Uranium Mill Licenses" and Regulatory Guide 3.8, "Preparation of Environmental Reports for Uranium Mills". The stated purpose of the Guides was "to describe and make available to the public methods acceptable to the AEC regulatory staff of implementing specific parts of the Commission's regulations, to delineate techniques used by the staff in evaluating specific problems or postulated accidents, or to provide guidance to applications". The Guides further stated that:

> ". . . regulatory guides are not substitutes for regulations and compliance with them is not required. Methods and solutions different from those set out in the guides will be acceptable if they provide a basis for the findings requisite to the issuance or continuance of a permit or license by the Commission."

AEC's successor, the Nuclear Regulatory Commission, has published a number of regulatory guides. Each, including revised Guide 3.8, contains exactly the same stated purpose as the AEC regulatory guides.

In theory, the purpose of the guidelines was to inform the applicant of what would be required while allowing flexibility. Under the NRC, the guidelines have been administered more like regulatory "requirements" than regulatory "guides".

While the NRC has continued to insist that regulatory guides are only guidelines, non-adherence to the "suggestions" in the regulatory guides has usually resulted in substantial delay in obtaining a license or in heavy pressure by the NRC to conform to the guidelines. In short, flexible regulatory guides have become rigid regulatory requirements in practice.

When regulatory guides began to impede the orderly and timely processing of license applications, NRC shortcircuited the regulatory guide process. The industry began to see what the NRC called "branch positions" and "performance objectives" which reflected the NRC's current position regarding "target criteria" and "alternative or upper limit criteria" and the objectives an applicant should seek to achieve. As with the regulatory guides, industry has found it increasingly difficult to obtain a license from the NRC when the "recommendations" provided by the NRC in the branch positions on performance objectives are not followed to the letter.

Preparation of the Draft GEIS

The foregoing describes the regulatory climate that existed when NRC announced that it would prepare a generic environmental impact statement (GEIS) on uranium milling. The expressed purpose of the draft GEIS is "to assess the potential environmental impacts of uranium milling operations, in a programmatic context, including the management of uranium mill tailings, and to provide an opportunity for public participation in decisions on any proposed changes in NRC regulations based on this assessment". (See Draft GEIS, p. 2). The principal objectives of the draft GEIS are (Draft GEIS, Summary, p. 2):

1. To assess the nature of the environmental impact of uranium milling in the United States from local, regional and national perspectives on both short and long-term bases, to determine what regulatory actions are needed;
2. More specifically to provide information on which to determine what regulatory requirements for management and disposal of mill tailings and mill decommissioning should be; and
3. To support any rulemaking that may be determined to be necessary.

In light of NRC's past licensing practices, the industry at first welcomed the announcement of this generic assessment of uranium milling. It was assumed that a *de novo* re-examination of the existing regulatory structure would occur and that only those regulations that proved to be scientifically justified from an environmental and public health standpoint would be promulgated.

In reality the draft GEIS has turned out to be essentially a self-serving attempt to legitimize the prior NRC policy as set forth in existing regulatory guides, branch positions and performance objectives. The draft GEIS studies the impacts of these past policies without ever accomplishing the stated principal objective of establishing a regulatory program based upon a thorough and impartial analysis of the industry -- not on predetermined policies.

Derivation of the Proposed Regulations and Licensing Criteria

A careful analysis of the proposed regulations and licensing criteria reveals that they are derived from prior NRC regulatory guides, branch positions and performance objectives. Examples of this are discussed below.

1. Performance Objective No. 1: This performance objective states[_/] that one should strive to "locate the tailings isolation area remote from people so that population exposures would be reduced to the maximum extent reasonably achievable".

Draft GEIS: The proposed regulatory action in Section 12.2.1 (Item 8) of the draft GEIS recommends that "the tailings disposal site should be located in an area remote from people to reduce population exposures to the maximum extent reasonably achievable and to reduce the likelihood of human intrusion into the area".

[_/] The performance objectives quoted appear in Scarano, Ross A. & Linehan, John J., "Current U.S. Nuclear Regulatory Commission Licensing Review Process: Uranium Mill Tailings Management," published in Proceedings of a Symposium on Uranium Mill Tailings Management (November 20-21, 1978), Vol. 1, Colorado State University.

Proposed Regulations: As might be expected, Proposed Criterion No. 1 states that "tailings or waste disposal areas shall be located at remote sites so as to reduce potential population exposures and the likelihood of human intrusions to the maximum extent reasonably achievable."

2. Performance Objective No. 2: This performance objective states that one should "locate the tailings isolation area such that the disruption and dispersion by natural forces is eliminated or reduced to the maximum extent reasonably achievable."

Draft GEIS: The first proposed regulatory action in the draft GEIS, Section 12.2.1, Technical Siting and Design Requirements, states that "the tailings disposal area should be located in an area where disruption and dispersion by natural forces are eliminated to the maximum extent reasonably achievable."

Proposed Regulations: Proposed Criterion No. 2 states that "tailings or waste disposal areas shall be located at sites where disruption and dispersion by natural forces are eliminated or reduced to the maximum extent reasonably achievable."

4. Performance Objective No. 4: This performance objective states that one should strive to "eliminate the blowing of tailings to unrestricted areas during normal operating conditions."

Draft GEIS: Section 12.2.1 of the draft GEIS (Item 7) proposes as a regulatory action, that "milling operations shall be conducted so that radiation protection limits applicable to offsite individuals and specified in 10 CFR 20 and 40 CFR 190 are met." Unless tailings are effectively sheltered from wind the proposed regulations provide that portions not covered by standing liquids should be wetted or chemically stabilized to prevent or minimize blowing and dusting to the maximum extent reasonably achievable.

5. Performance Objectives Nos. 5 and 6: Objective 5 states that one should strive to "reduce direct gamma radiation from the impoundment area to essentially background." Performance objective 6 states that one should attempt to "reduce the radon emanation rate from the impoundment area to about twice the emanation rate in the surrounding environs."

Draft GEIS: The proposed regulatory action in Section 12.2.1 of the draft GEIS (Item 5) requires that "sufficient cover should be placed over the tailings to result in a calculated surface exhalation of radon resulting from the tailings of less than 2 pCi/l per second; that is, incremental releases of radon above that resulting from radon occurring naturally in cover materials shall be less than 2 pCi/l per second. Direct gamma exposure from the mill tailings should be reduced to background levels."

Proposed Regulations: Criterion No. 6 of the proposed regulations requires that "sufficient earth cover but not less than 3 meters, shall be placed over tailings or wastes at the end of the milling operations to result in a calculated reduction in surface exhalation of radon from the tailings or wastes to less than 2 pCi/l per second above natural background levels. Direct gamma exposures from the tailings or wastes should be reduced to background levels."

6. Performance Objective No. 7: This objective requires the licensee to "eliminate the need for an on-going monitoring and maintenance program following successful reclamation."

Draft GEIS: Section 12.2.1 of the draft GEIS (Item 4) requires that "final disposal of tailings should be such that on-going active maintenance is not necessary to preserve isolation."

Proposed Regulations: Criterion No. 5 of the proposed regulations requires that "the final disposition of tailings or wastes at milling sites should be such that the need for on-going active maintenance is not necessary to preserve isolation."

7. Performance Objective No. 8: This objective would "provide surety arrangements to assure that sufficient funds are available to complete a full reclamation plan."

Draft GEIS: Section 12.2.2, Supplementary Institutional and Procedural Requirements, of the draft GEIS (Item 4) provides that "financial surety arrangements must be established to insure that sufficient funds will be available for disposal and reclamation of mill tailings and decommissioning the site and buildings in accord with the approved plan discussed in 12.2.1 above."

Proposed Regulations: Criterion No. 9 of the proposed regulations provides that "financial surety arrangements shall be established by each mill operator to assure that sufficient funds will be available to carry out the decontamination and decommissioning of the mill and site and for the reclamation of any tailings or wastes disposal areas."

8. Below Grade Disposal Objective: In a document titled, "Fuel Processing and Fabrication Branch Position Regarding Use of Uranium Mill Tailings in Construction of Mill Tailings Dams," NRC policy was stated as ". . . based on recent evaluations of tailings management alternatives for new mill proposals within NRC jurisdiction, the NRC would encourage the agreement states to consider the elimination of surface disposal of tailings regardless of the dam construction materials proposed. The major reason for requiring some form of below grade disposal system is that such disposal clearly provides greater assurance that the buried tailings will not be disturbed by man or by natural phenomena over the long term." (This document was distributed to the Colorado Division of Radiation and Hazardous Waste Control at a meeting held on May 26, 1978 between the Division and the NRC). This position was reaffirmed in a speech given by an NRC official at the earlier-referenced Uranium Mill Tailings Management Symposium held on November 21 and 22, 1978, at Colorado State University.

Draft GEIS: Section 12.2.1 of the draft GEIS (Item 2) provides that the "prime option" for disposal of tailings is "placement below grade either in mines or specially excavated pits."

Proposed Regulations: Criterion 3 of the proposed regulations indicates that "the prime option for disposal of tailings is placement below grade either in mines or especially excavated pits."

Conclusions

These are just a few examples of how regulatory guides, branch positions, and performance objectives have found their way into the draft GEIS and proposed Regulations. The 12 recommendations of the draft GEIS and the proposed regulatory criteria are essentially repetition of NRC's performance objectives. The draft GEIS is merely an attempt to legitimatize NRC performance objectives -- not an independent, objective analysis of the environmental impacts, costs, benefits and cost/benefit tradeoffs of uranium milling.

The purpose of NRC's enforcement guides, initially, was to inform applicants of what would be required to obtain a license while allowing flexibility on a site specific basis. Experience has shown that flexible regulatory "guides" became rigid regulatory "requirements" in practice. Since the proposed regulatory criteria are essentially a restatement of NRC's prior regulatory guides, branch positions, and performance objectives, AMC is concerned that the regulatory criteria will be administered in a similarly inflexible manner. Although the draft GEIS repeatedly stresses the importance of flexibility and the need to consider site-specific factors, the requirements in the draft GEIS are quite rigid when examined in the context of actual experience.

The draft GEIS is not an objective analysis of the potential environmental impacts of uranium milling operations nor does it justify the proposed regulatory actions. Although NRC guides and performance criteria, now incorporated into the regulatory criteria, have never been subject to rulemaking procedures, the draft GEIS assumes their legitimacy and proceeds to examine the effects of the proposed regulations. This is a circumvention of the rulemaking process. The NRC guides and performance criteria were not designed, nor were they intended, to form the necessary scientific and administrative basis for formal regulations; nor was compliance with them intended to be mandatory throughout the uranium milling industry. If NRC now desires to impose them as regulatory requirements, it should do its job and establish that regulations are needed.

PART III

H. CONCERNS WITH THE PROPOSED CRITERIA

H. CONCERNS WITH THE PROPOSED CRITERIA

In conjunction with the publication of the draft Generic Environmental Impact Statement on Uranium Mills, the NRC has proposed regulations establishing requirements for licensing a uranium mill. The proposal includes "Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes". These criteria are extremely important since they establish "technical, financial, ownership, and long-term site-surveillance requirements relating to the siting, operation, decontamination, decommissioning and reclamation of mills and tailings or waste systems and sites at which such mills and systems are located" (44 Fed. Reg. 50020).

The AMC is concerned with the bases for the criteria, as well as with the requirements of the criteria themselves. According to the preamble (44 Fed. Reg. 50017) the criteria "were basically derived from the GEIS" and are based on three specific "guiding principles" which were, apparently, developed by the NRC staff. There is however, a basic inconsistency between the GEIS and the criteria. On the one hand, the GEIS repeatedly stresses the need for individual and site-specific licensing requirements because of the significant variations between uranium mills. The criteria, on the other hand, establish very specific requirements and "prime options" that are to be imposed in issuing milling licenses. This latter approach in effect precludes individual and site-specific considerations of each mill license application.

The American Mining Congress feels that the "Introduction" to the criteria should describe the specific public health goals that must be met by mill operators. It should make clear that there are various ways to meet these goals and that mill operators may use the methods and techniques they find most effective so long as the goals are met. Once this is done the NRC may wish to refer to some of the options available to a mill operator rather than establish "criteria" that will be applied uniformly.

The following comments focus on the specific proposed criteria and are, in effect, a summary of many of the comments submitted by the AMC on the draft GEIS:

> Criterion 1 - This provides that tailings or waste disposal areas "shall be located at remote sites". Obviously, in order to interpret the word "remote" it is necessary that there be a definition or explanation as to the public health goals meant to be achieved through this requirement. Once the public health goal is specified, the term "remote" should be defined.
>
> This criterion also provides that wastes from "small remote above-ground extraction operations" shall preferably be disposed of at large existing sites. Again, there is no relationship established between a small remote operation and any public health risks. If there are risks, what are they? Are they so significant as to require the haulage of the waste to another site? Further, it may even be preferable to dispose

of the wastes at the small remote site, but this cannot be determined without knowing the public health goal the criterion is designed to achieve.

Criterion 2 - This provides that tailings for waste disposal areas "shall be located at sites where disruption and dispersion by natural forces are eliminated or reduced to the maximum extent reasonably achievable." The words "reasonably achievable" must be defined for this requirement to have any meaning. The definition should provide that the costs of disposal be determined in conjunction with an analysis of any health risks that might be averted.

Criterion 3 - This provides that the "prime option" for the disposal of tailings is placement "below-grade" and further provides that above-grade disposal could be considered only if the applicant demonstrates "that an above-grade disposal program will provide reasonably equivalent isolation of the tailings from natural erosional forces". Here again, NRC should specify its health goal. If above-grade disposal can achieve an appropriate public health goal developed by NRC, it does not seem sensible to require below-grade disposal or any other specific disposal mode, particularly if it is more expensive.

Establishing a "prime option" is not appropriate since it creates a presumption in favor of one technique. The criterion merely should require the adequate disposal of tailings through the use of whatever method is most suitable for each specific site. A mill license applicant should be allowed to use any technique that meets the NRC health goal and not be required to compare and contrast other techniques that he does not intend to use, for example because of the site-specific nature of the mill.

Criterion 4 - This sets out six requirements that "shall be adhered to" if tailings are disposed of above ground. While some of these options may be appropriate for certain mills, they clearly would not all be applicable universally. The introductory sentence of the criterion should reflect that only the options necessary to meet the NRC goals shall be adhered to.

Further, certain of the options are too specific and would tend to preclude industry from developing other more effective approaches as technological advances are developed, e.g. the requirment for a self-sustaining vegetative cover or riprap. Another option should be added which would allow a license applicant to utilize any other techniques or methods which meet NRC's health goals.

Criterion 5 - This provides that steps "shall be taken to reduce seepage of toxic materials into groundwater to the maximum extent reasonably achievable". It goes on to suggest that this could be accomplished by "lining the bottom of tailings areas", and other methods. It says that the "primary method" of protecting groundwater "shall be isolation of tailings and tailings solution". Again, the designation of a "primary method" imposes a presumption which must be overcome by the license applicant. If groundwater is adequately protected, there is no need for a preferred option or a "primary method". Specific changes in the wording are included in the attachment labeled "Appendix -- Groundwater Protection".

Criterion 6 - This provides that radon exhalation from tailings piles must be reduced to less than 2 picocuries per square meter per second above natural background levels. It is more than a little unclear as to why this specific level of radon exhalation was selected by NRC. There is certainly no support for this number in the draft GEIS. The AMC seriously questions the need for the 2 picocurie limit, and urges that a range of limits be selected for the final regulations which is justified by scientific and health risk data and that the limit for each particular site be selected from this range based on site-specific considerations.

Further, the criterion provides that at least three meters of each cover "shall be placed over tailings or wastes at the end of milling operations". Even assuming that the 2 picocurie level is necessary (which we seriously question), there does not appear to be any reason to require a minimum of three meters of cover to reach this level. Recent licensing activities by NRC have demonstrated that a combination of compacted clay and natural earthen cover can result in a calculated reduction of radon to less than 2 picocuries with less than three meters of natural cover. Also, the monetary cost of meeting the three meter requirement far exceeds any benefit to be derived by eliminating a minute increment of additional radon attenuation. Finally, if indeed a single fixed flux level is adopted, operators should be allowed to meet that level using whatever methods are available to account for the site-specific considerations.

Criterion 7 - This provides that certain pre-operational monitoring during construction be carried out. These requirements do not specify or limit how the monitoring must be done, and they thus allow operators to use monitoring techniques most effective for site-specific conditions. To the extent there is a need for such monitoring, this is an example of the type of criterion that allows adequate flexibility.

Criteria 8 and 8A - These provide that airborne releases from milling operations must be reduced to levels which are as low as reasonably achievable, primarily through the use of emission controls. They also specify that when necessary tailings should be wetted or chemically stabilized to prevent blowing. Daily inspections of tailings are required. Assuming there is a need for the requirements, they are proposed in a form that will allow mill operators to reduce airborne emissions and to perform daily inspections in whatever manner is most effective for their specific operations. Such flexibility should appear in the other proposed criteria as well.

Criterion 9 - This provides that financial surety arrangements shall be established by each mill operator to assure adequate decontamination, decommissioning and reclamation activities are carried out. The provisions themselves are too inflexible -- the six options allowed by NRC should be expanded. Specific changes in the wording of Criterion 9 are included in the attachment labeled "Appendix -- Financial Surety Arrangements". Additional detailed comments on financial surety arrangements are set forth in Part III, Item E.

Criterion 10 - This provides that a specific amount of money be paid by each mill operator to cover the cost of site-surveillance after the decommissioning of the mill. These also need more flexibility and should be expanded to provide it. For example, if it is determined that the site-surveillance will be more expensive than the initial amount, the Commission may increase the amount of money to be paid by the operator. There should also be a provision that if it is determined the initial amount of money is too great, the mill operator would have to pay less. Specific changes in the wording are included in the attachment labeled "Appendix -- Surveillance Costs." See also, Part III, Item E.

Criterion 11 - This sets forth the requirements for site and by-product material ownership. Assuming their need, these provisions seem adequate and reasonable, and provide adequate flexibility.

Criterion 12 - This requires that the final disposition of tailings should be such that "active maintenance is not necessary to preserve isolation". This establishes passive maintenance as a specific requirement in mill licensing and ignores the need for site-specific considerations recognized and encouraged in the draft GEIS.

More important however is the fact that this requirement exceeds the statutory directive in Section 161(x) of the Atomic Energy Act which provides that the NRC may establish regulations to insure that the need for long-term maintenance and monitoring of tailings after termination of a license "be minimized and, to the maximum extent practicable, eliminated". There has been no showing that it is practicable to require passive maintenance, and thus the criterion should be modified to allow, where appropriate, active maintenance.

APPENDIX -- GROUNDWATER PROTECTION

The current language of criterion 5 should be deleted and the following inserted:

> "Criterion 5 - The specific method or combination of methods of tailings disposal systems for mitigating toxic materials migration must be worked out on the site-specific basis. The system shall be selected and designed to minimize, and to the maximum extent reasonably achievable, the movement of toxic materials into the groundwater beyond the mill property boundary if such movement would create adverse health effects. Liners may be appropriate in some cases to protect groundwater quality and inappropriate in others. For instance, where natural soils provide an effective barrier against migration of harmful concentrations of toxic materials into or through the groundwater beyond the mill property boundary, barrier liners will not be required. Site-specific tests and analysis conducted in accordance with prudent scientific methods shall be provided as appropriate to assess the impact of the proposed tailings disposal system and allow the staff to evaluate the effectiveness and benefits of the proposed system."

APPENDIX -- SITE SURVEILLANCE COSTS

Criterion 10 - A one time charge of $250,000 to cover the costs of long-term surveillance shall be paid by each mill operator to the general treasury of the United States or to an appropriate State agency prior to the termination of a uranium or thorium mill license. If site surveillance requirements at a particular site are determined, on the basis of a site-specific evaluation, to be significantly greater or less than those specified in Criterion 12, variance in funding requirements ~~may~~ shall be specified by the Commission or other licensing authority. The total charge to cover the costs of long-term surveillance shall be such that, with an assumed 1 per cent annual real interest rate, the collected funds will yield interest in an amount sufficient to cover the annual costs of site surveillance. ~~The-charge-will-be-adjusted-annually-to-recognize-inflation. The-inflation-rate-to-be-used-is-that-indicated-by-the-change in-the-Consumer-Price-Index-published-by-the-U.-S.-Department of-Labor,-Bureau-of-Labor-Statistics.~~

The Criteria established pursuant to requirement category II (Financial Criteria) shall become effective upon both (1) the final promulgation by the Commission of the regulations implementing the conclusions and recommendations of the generic environmental impact statement on uranium milling (NUREG-0511); and (2) the final promulgation of standards by the Administrator

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of the Environmental Protection Agency pursuant to Section 275(b) of the Atomic Energy Act of 1954 as amended by Section 206 of the Uranium Mill Tailings Radiation Control Act of 1978 (P. L. 95-604).

APPENDIX -- FINANCIAL SURETY ARRANGEMENTS

Criterion 9 - Financial surety arrangements shall be established by each mill operator to assure that sufficient funds will be available to carry out the decontamination and decommissioning of the mill and site and for the reclamation of any tailings or waste disposal areas. A mill operator may submit a combination of financial surety arrangements which, taken together, will assure that sufficient funds will be available. The amount of funds to be ensured by such surety arrangements shall be based on cost estimates in an approved plan for (1) decontamination and decommissioning of mill buildings and the milling site to levels which would allow, to the extent reasonably practicable, unrestricted use of these areas upon decommissioning, and (2) the reclamation of tailings and/or waste disposal areas in accordance with technical criteria delineated in Section 1 of this Appendix, less the projected net worth, including assets which may be liquidated, of the licensee at the time of such decontamination, decommissioning or reclamation. Should the licensee have sold uranium to the United States prior to 1971, the amount of surety required under this Criterion shall be established on a pro rata basis such that the licensee will furnish surety only for that portion of the cost estimates in the approved plan which are attributable to other than such sales. The licensee shall submit this plan in conjunction with an environmental report (if an environmental impact statement is not required) that addresses the expected environmental impacts of the milling operation, decommissioning and tailings reclamation, and evaluates alternatives for mitigating these impacts. The surety shall cover the payment of the one time charge for long-term surveillance required by Criterion 10. In establishing specific surety arrangements, the licensee's cost estimates shall take into account total capital costs that would be incurred if an independent contractor were hired to perform the decommissioning and reclamation work but excluding costs which are attributable to interim decommissioning and reclamation work performed by a licensee during milling operations. In order to avoid unnecessary duplication and expense, the Commission will accept financial sureties that have been consolidated with financial or surety arrangements established to meet requirements of other Federal or State agencies and/or local governing bodies for such decommissioning, decontamination, reclamation, and long-term site surveillance. The licensee's surety mechanism will be reviewed from time to time by the Commission (generally at the time of license renewal) to assure sufficient funds for completion of the reclamation plan if ~~the-work-had-to-be-performed by-the-regulatory-authority~~ an independent contractor were hired to perform the decommissioning and reclamation work. The amount of surety liability ~~should~~ may increase or decrease at the time of license renewal in accordance with the predicted cost of future reclamation, or may remain static depending [illegible] the licensee's projected net worth. Factors affecting reclamation cost estimates include: inflation, increased in the amount of disturbed land; and decommissioning and reclamation that has been performed. This will yield a surety that is at least sufficient at all times to cover the costs of decommissioning and reclamation of the areas that are expected to be disturbed before the next license renewal. The term of the surety mechanism shall remain in effect until the reclamation program has been completed and approved, or until such time as title to the site is transferred to the governmental agency responsible for long-term surveillance, whichever comes first. Financial surety arrangements generally acceptable to the Commission are:

(a) Surety bonds;

(b) Self insurance;

(c) Guarantee by a state governmental agency, a local governmental agency, or by a third party which could qualify for self insurance as specified in (c);

(d) Cash deposits;

(e) Certificates of deposit;

(f) Deposits of government securities;

(g) Letters or lines of credit; and

(h) Combinations of the above or such other types of arrangements as may be approved by the NRC.

PART III

I. NEED FOR NRC DISCRETION IN IMPLEMENTATION OF EPA FUEL CYCLE REGULATIONS

I. NEED FOR NRC DISCRETION IN IMPLEMENTATION OF EPA FUEL CYCLE REGULATIONS

Portions of the draft GEIS and proposed regulations are designed to implement the EPA uranium fuel cycle standards (40 C.F.R. 190) which take effect in 1980. The draft GEIS identifies the steps that should be taken to control particulate emissions in accordance with this standard (draft GEIS, page 10). Because of the relationship of these regulations with the issuance of mill licenses, and in view of the fundamental defects in the bases of the regulations (as outlined below) the NRC must use great discretion when interpreting and implementing 40 C.F.R. 190.

These EPA regulations were proposed on May 29, 1975 (40 Fed. Reg. 23420). The American Mining Congress and others submitted written comments to EPA questioning the scientific validity of the standard. In its comments (copy enclosed) AMC states:

> "Twenty-five millirems per year is a very small dose rate, scarcely measurable with present field or plant instrumentation. It is less than cosmic radiation at sea level in the United States, and corresponds roughly to the increase in cosmic radiation which takes place between sea level and 6,000 feet elevation. It is less than normal gamma-ray background in anybody's backyard."

The AMC comments go on in great detail to criticize specific scientific information upon which the standards are based.

Of greater significance in the context of NRC's present regulatory proposals is the testimony presented at the March 8, 1976, EPA public hearing by the Nuclear Regulatory Commission Director of the Division of Siting, Health and Safeguard Standards. In this testimony (copy attached) the NRC discusses the advisability of promulgating the EPA standards. The Commission violently objects to the EPA scientific analysis, cost analysis, risk analysis, and supposed need for the standard. In the initial portion of the testimony, the NRC states "In simplest terms, we believe that the public interest would not be served by this proposed addition to the existing regulatory framework" (Testimony, page 3). It goes on to say:

> "As we show in this statement and in the attached staff analysis, we believe there has been an incomplete analysis of the costs and benefits of the proposed 40 C.F.R. Part 190. The Draft Environmental Impact Statement is deficient in important areas which are not corrected by the Supplementary Information issued on January 5, 1976. Even with these deficiencies, the partial cost analyses which were performed to show that the benefits to be derived from the standard do not justify the costs of its implemention. In this regard, we believe that there has been serious underestimation of the <u>real</u> costs of compliance with the standard and in overestimation of potential benefits which would result. [Testimony, page 4, emphasis in original].
>
> * * * * *
>
> . . . [T]he proposed approach in 40 C.F.R. Part 190 emphasizes <u>environmental</u> monitoring which, for the extremely low radiation levels of interest here, has been proven to be highly inaccurate even with the most sophisticated measurement devices. The inaccuracy of environmental monitoring for extremely low levels of radioactive materials cannot be remedied by costly development of instrumentation because the low levels of man-made radiation in the environment are small compared to levels of natural radiation. In addition, the inherent variability of climatic and other environmental conditions, including background radiation, seriously detracts from the practicability of using environmental monitoring to demonstrate compliance with the proposed standard [Testimony, pages 5-6, emphasis in original].
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> * * * * *

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> We have three kinds of specific concerns with the proposed standard; first, we believe that the analysis has not correctly assessed radioactive effluent control technology and the practicability of compliance with the proposed standards; second, we believe that the proposed standard would be impracticable to implement for technical and economic reasons for major components of the uranium fuel cycle; and third, we believe that it will be impossible to demonstrate, using environmental monitoring, either compliance or noncompliance at the low levels specified in the standard. [Testimony, page 7].
>
> * * * * *
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> . . . [T]he proposed radiation limits, as they would apply to reprocessing plants and to tailings piles at operating uranium mills, have no basis in commercial scale operating data. There simply are insufficient data from which to judge the feasibility of the proposed standard. Since no cost/benefit basis has been provided for the selection of the numerical values, we must conclude that there is a high risk that compliance with this standard also would be impracticable for uranium mills and reprocessing plants. . . Furthermore, since the proposed standard does not allow for variance in the event of demonstrated impracticability on a case-by-case basis, implementation of this standard would create a high financial risk in the allocation of corporate resources to fuel cycle facilities because of the uncertain risk of shutdown of those facilities." [Testimony, page 9].

Attached to the NRC testimony was "Attachment A" which was a written analysis by NRC of the proposed regulations. The portion of this Analysis that deals with uranium mills states in part:

> "Tailings piles are subject to erosion by wind as the solid material dries. Airborne radioactive material from these tailings is extremely variable and representative samples obtained from monitoring programs are difficult to evaluate with respect to estimating potential dose equivalence on a yearly average basis for the lifetime of the facility. Furthermore, sufficient data on airborne radioactive material

> from tailings to estimate potential doses from all exposure pathways does not exist. The source term characterization presented in the ORNL studies and cited by EPA . . . are based primarily, on *calculations* which require the selection of *parametric* values, for which data are not available, and represent judgment which has not been verified by measurements. The estimated source terms and calculated potential doses *do not* contribute the needed data base required to select the values in the proposed standard or to judge the feasibility of complying with the proposed standard.
>
> *. . . NRC staff is not aware of any method which has been demonstrated to provide stabilization of active tailings piles sufficient to assure compliance with the proposed standard. Further, we are not aware of any cost effectiveness evaluation provided by EPA for stabilization of mill tailings."* [NRC Analysis, pages 33-34, emphasis in original].

The NRC Analysis also discusses the health effects of the EPA standards:

> "The data available today do not rule out a *zero* risk from low doses delivered at low dose rates. Thus, we believe that when integral population doses are calculated from low doses at very low dose rates and related to calculated health effects, a *factually correct statement would be that the number of health effects is likely to be within the range from zero to N, where N is the value calculated using the linear theory*. Since cost effectiveness is judged by EPA in considering the cost of averting potential health effects, it is important to realize that *if* the health effects are indeed zero, any cost realized to reduce the value is not justified from a health viewpoint." [NRC Analysis, page 39, emphases in original].

With regard to economic considerations, the NRC states:

> "EPA does not explain how dose limits for individuals were justified by '. . . weighing cost-effectiveness and cost of control relative to the total capital cost . . .' If the values selected for the annual dose limits for individuals are justified only on the basis of the cost of controls relative to the capital cost of the facility, the procedure would not preclude arbitrary decisions to require controls which are not cost-effective." [NRC Analysis, page 41, emphasis in original].

In view of the tremendous shortcomings of 40 C.F.R. 190, the NRC should exercise considerable care and discretion in developing its program to implement the EPA regulations. Since the regulations, according to the NRC testimony, are unfounded and unnecessary, the Commission should carefully consider how best to reasonably implement and enforce the requirements.

The AMC urges the Commission to exercise its discretion to interpret, in a reasonable and meaningful way, the EPA regulations so that individual mill and mill site characteristics, will be the paramount consideration in licensing and compliance determinations. Because of the deficiencies of the EPA regulations, the burden is now on NRC to implement the regulations so as to protect public health while assuring necessary uranium production for current and future energy needs and for the common defense and security of the United States.

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July 28, 1975

Director
Criteria and Standards Division (AW 560)
Office of Radiation Program
Environmental Protection Agency
Washington, D. C. 20460

Dear Sir:

Subject: Standards for Environmental Radiation Protection for Nuclear Power Operations, 40 CFR Part 190, Proposed *Federal Register* May 29, 1975

In response to the invitation in the *Federal Register* May 29, 1975, the American Mining Congress hereby submits the following comments on proposed environmental standards for the nuclear fuel cycle, 40 CFR Part 190. The American Mining Congress is a national trade association of the mining companies that produce most of the nation's metals and industrial, agricultural and other minerals, including the uranium mining and milling firms responsible for most of the uranium oxide production in the United States.

The American Mining Congress objects to the proposed regulations, particularly as to their application to the uranium milling industry. These objections are based on the analysis of EPA's proposed standards and the referenced documents cited in support of this proposal, prepared by Dr. Robley D. Evans for the American Mining Congress. A copy of Dr. Evans' letter of July 18, 1975 is enclosed and is included as a part of the AMC statement.

We will appreciate a careful review of these comments.

Sincerely,

J. Allen Overton, Jr.

J. Allen Overton, Jr.
President

Enclosure

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ROBLEY D. EVANS
4621 EAST CRYSTAL LANE
SCOTTSDALE, ARIZONA 85253

July 18, 1975

Mr. J. Allen Overton, Jr., President
American Mining Congress
1100 Ring Building
Washington, D. C. 20036

Subject: EPA's proposed new 40CFR190

Dear Mr. Overton:

This is to confirm and summarize my previous reports to Mr. Johnson particularly with respect to the impact of the proposed rule 40CFR190 on uranium mills.

Reference will be made to the EPA's discussion of the proposed rule as published in the Federal Register for May 29, 1975, pp. 23420-23425 (hereafter called "FR"), to EPA's "Draft Environmental Statement: Environmental Radiation Protection Requirements for Normal Operations of Activities in the Uranium Fuel Cycle" (hereafter "ES") dated May 1975, to their "Environmental Analysis of the Uranium Fuel Cycle, Part I - Fuel Supply", EPA-520/9-73-003-B, dated October 1973 (hereafter "EA"), and to the BEIR Committee's report dated November 1972, (hereafter "BEIR") referred to on FR page 23420, column 2, and used by EPA as the primary basis of their estimates of health effects.

The application of the present proposed rule 40CFR190 to uranium milling is discussed mainly in the middle paragraph of FR p. 23422, column 1. The EPA notes that the impact on populations due to off-site effluents from uranium milling should generally be small because of their "predominantly remote locations and lack of widespread dispersion.". The governing rule for uranium mills would be only that part of para. 190.10(a), FR p. 23424, which specifies a maximum annual dose equivalent of 25 millirems to any organ of any member of the general public, because milling operations do not contribute significantly to whole-body γ-ray exposures off-site, and they do not generate any radioactive isotopes of iodine which could contribute to a thyroid dose.

Twenty-five millirems per year is a very small dose rate, scarcely measurable with present field or plant instrumentation. It is less than cosmic radiation at sea level in the United States, and corresponds roughly to the increase in cosmic radiation which takes place between sea level and 6000 ft. elevation. It is less than the normal gamma-ray background in anybody's back yard. It is comparable with the gonadal irradiation by the potassium-40 found in all normal human muscle tissue.

There appear to be major inconsistencies between EA, ES, and 40CFR190, with respect to releases from mills, which should be clarified by EPA before adoption of 40CFR190, especially if EA is ever to be referred to by NRC for guidance in evaluating compliance with 40CFR190.

The major unresolved problem with respect to mill effluents is as follows. Paragraph 190.10(a) of 40CFR190 reads in part, "The annual dose equivalent shall not exceed ... 25 millirems to any other organ of any member of the public ...". By "<u>any member of the public</u>" I would understand, under the definitions in 40CFR190, Subpart A, paragraph 190.02(c) and (d), any "off-site" location. To me, this means that the 25 mrem/yr applies at the plant boundary, i.e., it's a "fence post value". This would be in accord with EPA's remarks about protection of individuals who live near a site boundary (FR p.23421, column 2), rather than averaging over a population area.

Dosimetrically the organ which is primarily at risk from airborne mill effluents is the lung. The skeletal and whole-body doses from water effluents are judged to be negligible compared with the lung dose wherever reasonable care is taken of waste water (e.g., EA, pp. 36-37). Regarding mills, the paragraph on mills in FR p. 23422 observes that the impact on populations due to offsite effluents should be small. The implication is clear that EPA expects that mills would have an easy time complying with 40CFR190.

Turning to the ES document of May 1975, this reassurance regarding mills such as Humeca, Highland, and Shirley Basin is found in Table 6 on page 54 and in the middle paragraph on page 57, where "... in the general environment ..." "... relatively small doses are projected to the lung and bone at mills ...". Note that Table 6 gives comfortably small dose-equivalent values, (misnamed "exposure"), but does not say where they apply. Possibly, from the text on page 57 they apply "in the general environment" (not quantitatively defined) rather than at the fence post.

The October 1973 EA document carries none of these assurances. This earlier EPA analysis considers a hypothetical "model mill" (p. 24) which annually processes 600,000 metric tons (MT) of ore

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and produces 1,140 MT of yellowcake, therefore containing 1000 MT of uranium element. The presumed airborne releases of U, Ra-226, and Th-230 from this mill are tabulated on p. 27. These seem to me to be incredibly small. For example, take the 0.1 Ci/yr release of uranium. Because of EPA's definition of a Ci of U (EA p. A-1) 1 MT of U is about 0.67 Ci. Thus the airborne annual release of U postulated is 0.15 MT, which is only 0.015% of the annual output of U. Aside from a small percentage of U left in the tailings or process water, this is a recovery of greater than 99.98%. The EPA describes dust control measures on EA pp. 40-41 and develops "... an effective system control of about 99%.". That's not 99.98%. The EPA's waterborne effluent control measures are described on pp. 44-50, and are also rated as giving less than 0.1 Ci U (p. 34) or 0.015% release from the site.

From these tiny airborne releases, EA then introduces a long series of ad hoc assumptions regarding lung dosimetry, which lead to a dose-equivalent of 450 mrem/yr to the lung at the plant boundary (EA p. 36 and p. A-20). On page 72 they call this the dose to "individuals that might live within 1 km of the plant". That's not "less than 25 mrem/yr". This lung dose from their "model mill" would seem to be in severe violation of the proposed 40CFR190. The skeletal dose attributed to drinking 2 liters per day of their postulated water released at the plant boundary is 13 mrem/yr (p. 37).

I suggest that EPA should clarify the apparent conflict between their 40CFR190 25 mrem/yr to any organ of any member of the public, and their estimated lung dose of 450 mrem/yr at the plant boundary of the "model mill". Both of these postulates cannot be simultaneously correct.

It may be noted that in several places the BEIR report points out that its use of a linear nonthreshold model at all dose-rates and all dose ranges is not based on radiobiological findings but rather is used as the only mathematically "workable approach to numerical estimation of risk in a population" (e.g., BEIR pp. 88, 89). The linear extrapolation from the dosage domain in which radiobiological effects are actually observed down to the dosage domain of radiation protection standards is often by a factor of more than a million. The extrapolated incidence of radiobiological effects at the level of the prudent radiation protection standards have been viewed as upper limits, since the introduction of the linear nonthreshold model for mathematical convenience in assessing dose commitments from atmospheric weapon tests by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) in

1958. The BEIR report's extrapolated value for this maximum absolute risk of lung cancer from α-particle irradiation of the bronchial epithelium is (BEIR, p. 150) 1 case/yr per million person-rems. Thus this risk to one individual receiving continuously a fence-post lung dose of 450 mrem/yr for 20 years is 1 in 100,000, a value which is many orders of magnitude below the natural incidence. The EPA's Environmental Analysis translates this lung cancer risk into a "health conversion factor" of 50 events/million person-rems (EA, Table 11, p. A-18) "over a period of years" (EA, p. A-19) without stating how many years. Overall, the EPA estimates the cost to industry of its proposed rule 40CFR190 "to be less than $100,000 per potential case of cancer, leukemia, or serious genetic effect averted", or "less than $75 per person-rem". This translates into 75/100,000 = 750 cases per million person-rem, which would be viewed by many radiobiologists as a very high estimate of the actual potential risk per rem.

Radon and radon daughter effluents are explicitly exempt from 40CFR190 at present (FR p. 23423, col. 1, and p. 23424, para. 190.10(a)). However "The Agency ... has underway an independent assessment of man-made sources of radon emissions and their management" (FR p. 23423, col. 1). The "Environmental Analysis ...", EA, written about 2 years ago devotes much space to the uranium mill tailings problem. Their treatments in EA of radon flux, migration, daughter product disequilibria, and dosimetry contain many serious scientific errors. Major qualitative and quantitative revisions will be required for any realistic evaluation of any process involving radon release, such as the uranium mill tailings piles.

One pretty obvious "suggestion" to EPA, which may apply to some companies which are members of the AMC, is to clarify whether the proposed rules 40CFR190 apply only to the <u>uranium</u> fuel cycle (as stated in Subpart B, para. 190.10, p. 23424) or to <u>any nuclear</u> fuel cycle (as stated in Subpart A, para. 190.01).

With best wishes.

Cordially yours,

Robley D. Evans

RDE:mms

Robley D. Evans

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September 15, 1975

Director
Criteria and Standards Division (AW 560)
Office of Radiation Program
Environmental Protection Agency
Washington, D. C. 20460

Dear Sir:

Subject: Standards for Environmental Radiation Protection for Nuclear Power Operations, 40 CFR Part 190, Proposed Federal Register May 29, 1975

By letter of July 28, 1975, the American Mining Congress submitted its comments on the proposed environmental standards for the nuclear fuel cycle, 40 CFR Part 190, published in the Federal Register May 29, 1975. The comments and objections were based on an analysis of the proposed standards prepared by Dr. Robley D. Evans.

The notice in the Federal Register August 15 extending the time for comment to September 15, 1975 has provided Dr. Evans with the opportunity to prepare additional comments on the proposed standards based on further studies of the subject matter. The American Mining Congress hereby transmits a copy of Dr. Evans' letter of September 10, 1975 as further objections by the AMC to the proposed regulations.

Your careful review of this material will be appreciated.

Sincerely,

J. Allen Overton

J. Allen Overton, Jr.
President

Enclosure

1545 182

Robley D. Evans
4621 East Crystal Lane
Scottsdale, Arizona 85253

September 10, 1975

Mr. J. Allen Overton, Jr., President
American Mining Congress
1100 Ring Building
Washington, D. C. 20036

... distributed as another membership service by the American Mining Congress

Subject: Additional comments on EPA's proposed new 40CFR190

Dear Mr. Overton:

The EPA having provided an extension of time (F.R. 40, 34417) for comments on 40CFR190, I would like to make the following supplement to the comments in my letter to you dated July 18, 1975.

In the third paragraph of that letter I assumed with EPA that "... milling operations do not contribute significantly to whole-body γ-ray exposures off-site...". However, one should consider the fact that near some older operating mills and inactive mills windblown particulates from the mills and especially from their associated tailings piles will have created local areas of higher than normal γ-ray background.

The possible impact of windblown particulates on the 25 mrem/yr provision in 40CFR190 has come to mind because I have had the opportunity this week to study portions of ORNL-TM-4903, Vol. 1, "Correlation of Radioactive Waste Treatment Costs and the Environmental Impact of Waste Effluents..." by M. B. Sears et al., also to examine some γ-ray survey data by the Colorado Department of Health, and to recall some of my own experiences while doing γ-ray surveys around homes in Grand Junction with the C.D.H. several years ago. A good many homeowners were convinced that a rich admixture of tailings sand in their gardens did wonders, especially for the roses, and γ-ray levels of 0.1 mR/hr or above were not uncommon for gardens.

The ORNL document states (on page 189) that "Both EPA and AEC-Regulatory have taken soil samples in the vicinity of tailings piles. No detectable increase has been noted in the off-site activity except where there has been visible migration of sand dunes.". However, scintillometer γ-ray surveys by C.D.H. personnel do tend to show far-from-pile γ-ray values such as 0.015 to 0.020

mR/hr but γ-ray values more in the domain of 0.02 to 0.03 mR/hr at distances of a few blocks from the tailings. These small differences are of no radiobiological consequence. However, the 25 mrem/yr provision of 40CFR190 corresponds to an average exposure rate of less than 0.003 mR/hr. Hence an elevation from 0.02 to 0.03 mR/hr corresponds to more than 3 times the 25 mrem/yr of 40CFR190 for planned releases.

Table 9.27 (on page 250) of the ORNL document gives some γ-ray exposure levels on the tailings pile and at an unstated but remote distance from the tailings for 4 well-known tailings piles, but unfortunately gives no γ-ray levels at distances such as 1/4 or 1/2 mile.

The entire matter of present γ-ray levels merits detailed study before any regulation at such low differential levels as 0.003 mR/hr is enacted. Indeed it may be permanently hopeless to identify locations near mills and tailings piles where new depositions of windblown particulates elevate preexisting local levels by 0.003 mR/hr.

Further, because a 20-year life is inherent in the planning of new mills, the future annual windblown particulate deposition of fixed activity (not removed by rain, etc.) could only correspond to 1/20th of 0.003 mR/hr or 0.00015 mR/hr per year, which simply cannot be measured reliably against a cosmic ray level of 0.006 mR/hr and an inhomogeneous local γ-ray level of the order of 0.01 to 0.02 mR/hr. Such a regulation would be unenforceable.

It may be timely to recall how small the proposed 25 mrem/yr is, as was mentioned briefly in the 4th paragraph of my letter of July 18, 1975. It is well known that no radiobiological effects have been observed in the populations of Guarapari, Brazil, and of the Kerala Coast of southwest India, who have lived for many generations on monazite sand, where the annual γ-ray exposure of some individuals exceeds 2000 mR/yr, or an average continuous level of about 0.23 mR/hr. On the Kerala Coast the epidemiological study involved a population of 13,000 households, involving 70,000 persons, and included over 13,700 pregnancies in over 2400 married couples. More than 10,000 personal TLD dosimeters were worn and showed that some 25% of the households experienced annual exposures exceeding 500 mR, 8.8% exceeded 1000 mR, and 1.1% exceeded 2000 mR. No epidemiological difference could be found between the residents of the Kerala Coast and those of Bombay where the total annual background radiation is about 100 mR.

COMMENTS FOR THE EPA HEARINGS ON MARCH 8-10, 1976

CONCERNING THE

EPA PROPOSED ENVIRONMENTAL RADIATION STANDARDS

40CFR190

BY ROBLEY D. EVANS, Ph. D.

ON BEHALF OF THE

AMERICAN MINING CONGRESS

MARCH 1976

INTRODUCTION

I appreciate this opportunity to supplement my earlier written comments on the Environmental Protection Agency's proposed standards 40CFR190, relating to the uranium fuel cycle, as submitted to the EPA by the American Mining Congress in July and September of 1975.

Issuance by the EPA in January 1976 of Supplements A through H is the occasion for these supplementary comments in the present hearings. I shall restrict my comments to three areas: first, matters discussed in the EPA's Supplement A concerning dosimetry and verification of compliance with respect to windblown tailings from active mill sites; second, matters discussed in the EPA's Supplement B concerning dose-vs.-effect assumptions, especially with respect to low-level gamma-ray and alpha-ray irradiation; third, matters discussed in the EPA's Supplement H concerning releases from the so-called "model mill", lung dosimetry, and estimated health effects.

I would like to take this opportunity to express my recognition of and appreciation for the evidently very large amount of effort which the EPA personnel have already devoted to various details of the environmental analyses of the multifaceted uranium fuel cycle. Many disciplines and subspecialties of science and engineering have to be invoked and coordinated. Much work remains to be done.

SUPPLEMENT A. WINDBLOWN TAILINGS FROM ACTIVE MILL SITES

In my commentary of September 10, 1975 concerning windblown tailings I pointed out that there are elevated gamma-ray levels around operating as well as inactive mills and tailings piles, created by windblown particulates, and exceeding 0.003 mR/hr (25 mrem/yr), but not generally exceeding the Surgeon General's "no remedial action level" (10CFR12, FR 37, 25919, 12/6/72) of 0.05 mR/hr above background. Some of these areas result from eave-drip or from trapping of windblown tailings by weeds and grasses. These elevated gamma-ray levels are of no radiobiological significance, and it is neither feasible nor radiobiologically necessary to decontaminate these areas.

An annual fixed deposition of airborne dust which would not exceed 25 mrem/hr of gamma-ray dose in its 20th year would have to be at a rate of only 0.00015 mR/hr per year, and could not be monitored or enforced. Supplement A responds affirmatively (p. 7) agreeing that "... verification on an annual, incremental basis ... would be unreasonable, since one mrem/yr is small compared to uncertainties in natural gamma-ray background levels.".

The basis for the choice of 25 mrem/yr in 40CFR190 is not evident. I suggest that it is an unnecessarily small and restrictive level, being so small that it cannot be measured in comparison with local variations and seasonal variations and uncertainties in the natural gamma-ray background levels. I propose instead the Surgeon General's "no remedial action level" of 0.05 mR/hr especially for gamma-radiation from windblown tailings.

The environs of 21 inactive uranium mill sites were the subject of extensive gamma-ray measurements reported in the EPA's

Las Vegas Facility Technical Note ORP/LV-75-5 titled "Gamma Radiation Surveys at Inactive Uranium Mill Sites", dated August 1975. Unfortunately this 83-page report seems to contain no original field-measurement results, e.g., raw data in mR/hr. Th findings seem to be reported only in a specialized unit called "uncorrected differential gamma reading - μR/h", being the diffe ence between scintillometer readings with and without a sliding lead shield of unstated geometry, thickness, and attenuation factor. If the raw data from this extensive field study are still available it would be useful to compile and distribute them in a scientifically meaningful form.

Supplement A, on pages 7 and 8, presents the results of dosimetric calculations of lung dose one kilometer downwind from a "typical pile" as a result of one millicurie/yr of airborn insoluble 0-10 μ particles, and of the gamma-ray exposure if an additional one millicurie/yr of 10-80 μ particles were "deposite in a ring one-half to one kilometer from the pile". The results are given as "approximately one mrem/yr to the lungs", and an increase in "gamma-ray exposure level of about 10 rem/yr".

The gamma-ray exposure calculation can be examined because the input assumptions are at least partially stated. It is state that one millicurie/yr of 10-80 μ particles "deposited in a ring one-half to one kilometer from the pile" yields a "surface contamination level of about 3 n Ci/m^2.". However if a uniform deposit of one millicurie over a circle of 1000 m radius is meant, then the surface contamination increment would be about 0.3 nanocuries/m^2 · yr, or a full order of magnitude less than stated. No combination of uniform deposit over a circle of radius between 0.5 and 1 km or of a doughnut-shaped area can lead to the stated value, in which even the dimensions are incorrect because "per year" has been omitted.

Continuing, I have calculated the gamma-ray exposure rate at the usual 1 meter height above a uniformly contaminated, smooth, horizontal plane surface from first principles, for the stated surface contamination level of 3 nanocuries/square meter. The result is not "about 10 μrem/yr" as stated on page 8 of Supplement A, but is about 300 μR/yr, or one and a half orders of magnitude higher. This calculation from first principles agrees, incidentally, with a value which can be read (with appropriate conversion of units) from Fig. A-2 on page 81 of EPA's document ORP/LV-75-5 discussed earlier.

The point of this detailed comment is that in the one instance where sufficiently explicit information is given concerning the input assumptions and source terms to permit "cross examination of the data" the dosimetric statements are found to be grossly inaccurate. Insufficient data are given to permit examination of the lung doses which are stated to result from EPA models and calculations, but it seems dubious to accept them at face value when order-of-magnitude errors are found in relatively simple dosimetric calculations which can be checked.

Appendix A, page 8, states that:

> "It does not appear at this time to be practical to measure the annual release of radionuclides from operational tailings piles to the air pathway. However, it is practical and reasonable to reduce these releases to very small values (< 1 mCi/yr) by application of control measures ...".

This statement appears inconsistent with the "model mill" parameters which are discussed in Supplement H.

The "model mill" processes 600,000 metric tons of 0.167% U ore per year (Supplement H, page 5), and therefore processes

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330,000 mCi of Ra per year, substantially all of which appears in the tailings pile. A postulated release to the air pathway of only 1 mCi of Ra per year presumes an airborne loss of only 1 part in 330,000 or about 3 parts per million of processed ta ings. Experienced environmental control and safety engineers major uranium-producing companies do not concur that a loss of only 3 parts per million is either practical or reasonable.

Further, Table 9.0-1 on page 32 of Supplement H appears t postulate ten times this airborne effluent from tailings beach by comparison of lines 5 and 6, where the difference between "controls" A2 + B3 and A2 + B3 + C2 (where C2 for tailings bea is defined in Table 8.1-1 on page 26) is 25 - 15 = 10 mCi/yr. This internal inconsistency of an order of magnitude between Supplements A and H remains unresolved.

In any case it needs to be recognized that each mill and tailings pile may present a special case, with optimum enginee procedures being dependent on local topography, weather condit and other parameters. Use of the Highland Mill as a universal "model mill" applicable to all locations and conditions is unrealistic. Mills and tailings piles must be considered on a case-by-case basis.

SUPPLEMENT B. DOSE-VS.-EFFECT ASSUMPTIONS FOR LOW-LEVEL GAMMA-RAY AND ALPHA-RAY IRRADIATION

The EPA Policy Statement on the "Relation Between Radiat Dose and Effect", dated March 3, 1975 states:

> "While the utilization of a linear, nonthreshold relation is useful as a generally applicable policy for assessment of radiation effects, (emphasis added) it is also EPA's policy in specific situations to utilize the best available detailed scientific knowledge in estimating health impact when such information is available for specific types of radiation, conditions of exposure, and recipients of the exposure. In such situations, estimates may or may not be based on the assumptions of linearity and a nonthreshold dose. ... "

In the basic reference document by Dr. Mildred B. Sears, et al. (ORNL-TM-4903-Vol. 1, May 1975) it is concluded that the radiation dose from resuspended airborne tailings during operation of a mill is ten times higher in bone than in other organs (p. 88). These doses are calculated by methods described in Appendix B (p. 83), but as of March 5, 1976 McKay had left ORNL and this reference (L. R. McKay, Ed., ORNL-4992, "A Methodology for Calculating Radiation Doses from Radioactivity Released to the Environment", 1975) had not yet been printed, according to the library manager at ORNL. This reference is essential to any quantitative review of the dosimetric calculations, and hence of the estimates of health effects regardless of what dose-vs.-response model is used. The nonavailability of ORNL-4992 precludes cross examination of most of the quantitative statements regarding dosimetry or health effects in the EPA Environmental Analyses (1973), the Draft Environmental Statement (1975), and Supplement H (1976).

There is a large body of detailed scientific knowledge concerning the health effects of internally deposited radium-226 in humans. Harrison Martland and others began such studies in the late 1920's and the subject has been under vigorous study in my laboratory and elsewhere for more than 40 years.

The dose-vs.-response relationship for radium-226 in humans is clearly not a linear relationship, and the quantitative aspect of the health effects in humans are not well represented by the many important studies which have been conducted using experimental animals, where species differences are profound. The human permissible body burden of 0.1 microcuries of radium-226 established from this work in 1941 has stood the test of time. It has also served as the reference standard or base line from which radiation protection standards for plutonium, radiostrontium and other bone-seeking internal emitters have been evaluated by combining the radium base line with radionuclide toxicity ratios measured in experimental animals, especially beagles.

It seems remarkable that this large body of experimental data on the health effects of radium-226 in humans, which now involves studies of more than 1700 persons, many with burden times extending beyond 50 years (Center for Human Radiobiology annual progress report to June 1975, ANL-75-60, Part II, p. 152 et seq.) has not been visibly considered by EPA in estimating health effects of radium-226 from mills or tailings piles. Because Supplement B, p. 1, states that:

> "No specific data were presented by commentators to indicate that any non-linear dose response model is applicable to exposures from the uranium fuel cycle",

it seems required to summarize some of the relevant findings from the extensive studies of radium in man.

Dose vs. Response for Radium-226 in Humans.

Radium is chemically similar to calcium, and hence following ingestion, inhalation, or injection the retained fraction is found predominantly in skeletal tissues. The health effects are related to the consequent alpha irradiation of skeletal tissues and the periosteal and endosteal cells on the surfaces of bone. At high doses osteomyelitis and spontaneous fractures may be seen, but the occurrence of two major categories of malignancy, sarcomas of bone and carcinomas of the mastoids or the paranasal sinuses, are of major importance as health effects.

Figure 1 shows the cumulative incidence or "occurrence" of radiogenic tumors in the "epidemiologically suitable" cases of persons whose burden-time and residual body burdens of radium-226 and -228 place them in one of nine dosage cohorts. The dosage cohorts vary by factors of 2 to 3 (e.g., 1000 to 2500 rads, 2500 to 5000 rads, etc.) where the skeletal dosage is expressed as the cumulative-rad dose (CR) averaged over all skeletal tissues. Figure 1 represents more than 600 human cases studied at the Massachusetts Institute of Technology between September 1934 and May 1969. It has been fully described in the literature, for example in the October 1970 Symposium at the University of Utah from which it was published as Chapter VII.1, pp. 431-468, of the Radiobiology of Plutonium, B. J. Stover and W. S. S. Jee, editors, J. W. Press, Dept. of Anatomy, Univ. of Utah (1972), under the title "Radiogenic Effects in Man of Long-Term Skeletal Alpha-Irradiation" by R. D. Evans, A. T. Keane, and M. M. Shanahan.

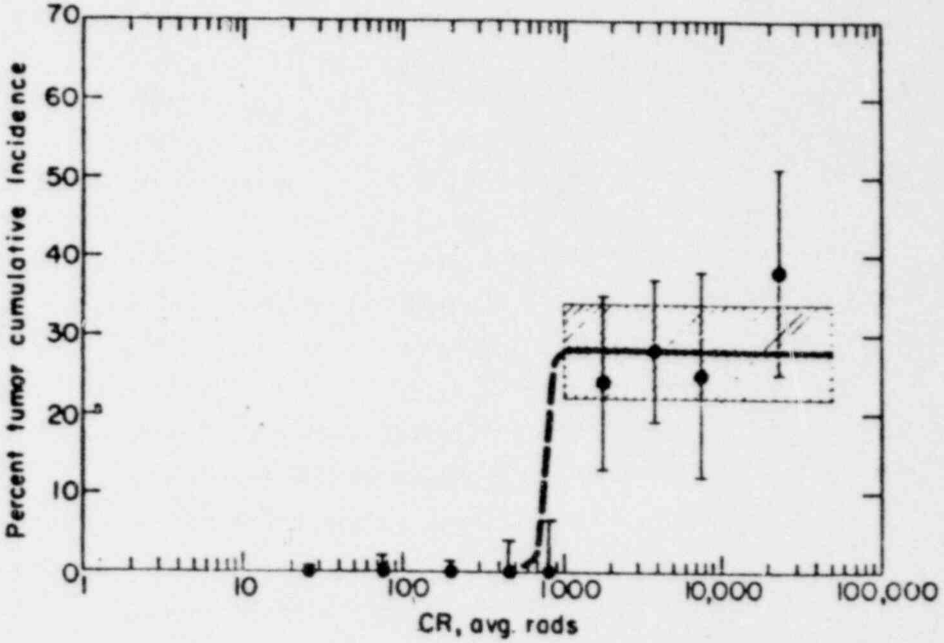

Figure 1. The observed radiogenic tumor cumulative incidence or occurrence in epidemiologically suitable unselected cases of humans with internal burdens of radium-226 and 228. CR is the cumulative rad dose averaged over all skeletal tissues. From Evans, Keane, and Shanahan (1972).

In Figure 1 no radiogenic tumors were observed in some 500 persons whose cumulative skeletal doses were less than 1000 rads. At higher doses the occurrence of radiogenic tumors was essentially independent of dose from about 1000 to 50,000 rads, and as indicated by the shaded region in Figure 1 has a mean occurrence of 28 ± 6%. At skeletal average doses below about 1000 rads, no tumors were seen, and a presumed sigmoidal transition region is shown dotted, with a relatively high tumor probability near the shoulder in the 800-to-1000-rad domain, and a finite probability in the 500-rad domain near the toe of the presumed sigmoidal transition region.

The UNSCEAR-ICRP linear nonthreshold model was first introduced by UNSCEAR in 1958 as a means of obtaining maximum estimates of the health effects of world-wide radioactive fallout from atmospheric weapon testing. A brief history of the development of the linear nonthreshold model for large-population radiation protection guides in the low-dose domain is given on pp. 448-453 of the chapter in the Radiobiology of Plutonium cited earlier. The UNSCEAR-ICRP linear nonthreshold model was chosen for obtaining prudent upper limits of risk in the low-dose domain on the basis of mathematical simplicity and not on radiobiological data for somatic effects in the low-dose domain. It involves starting at the dose domain in which the particular biological end point can be clearly quantified and extrapolating linearly to zero dose at the origin of coordinates.

This linear nonthreshold model would predict 14.6 radiogenic tumors where zero were observed below 1000 rads for the cases shown in Figure 1. Application of the binomial distribution to the data represented in Figure 1 showed that the statistical

probability that the actual observation of zero tumors is merely a statistical fluctuation from this linear nonthreshold model is 1 in 5 million repetitions of the study.

Clearly, this linear nonthreshold model is strongly rejected by these studies of human subjects.

As noted earlier, the combination of these studies with thos of Hasterlik, Finkel, Miller, et al. at ANL and ACRH, and hundred of new cases studied within the enlarged search program of the Center for Human Radiobiology since 1970 has already expanded the studied population to more than 1700 persons. It is still found that radiogenic tumors are not seen in the low dose domain. This increases the odds against this linear nonthreshold model by many orders of magnitude. There is no excess occurrence of leuke in the radium patients. The health effects of internal radium burdens in humans definitely do not follow the UNSCEAR-ICRP linea nonthreshold model.

Several other linear nonthreshold models have been suggested by individuals or groups. In general these are models of lesser slope than the UNSCEAR-ICRP model, and all of them give values higher than the observed occurrence at low doses (< 1000 rads) and very high doses (> 10,000 rads), and substantially lower than the observed occurrence at intermediate doses (about 1000 to 10,000 rads). These models have been reviewed and subjected to statistic tests for goodness of fit with the observed data in the paper by R. D. Evans, "Radium in Man", Health Physics 27, 497-510 (1974).

With respect to the BEIR committee's report and their linear nonthreshold model, some violence is done to the experimental data through internal contradictions, omissions, and arbitrary assumpti

First: the BEIR report discusses only bone sarcomas, and does not recognize the existence of the well-established occurrence of carcinomas of the mastoids and paranasal sinuses. Second: it uses exclusively the 1970 and 1971 compilations by the Center for Human Radiobiology (CHR) of cases studied in all laboratories without recognizing that more than half of the sarcoma cases in the M.I.T. and ANL-ACRH series which are blended in the CHR compilations are symptom-selected cases and are epidemiologically unsuitable for constructing dose-vs.-response relationships. Third: the BEIR report compresses the CHR dosage cohorts by lumping more than 500 human cases with dosages less than 500 rads into a single point plotted at zero rads on an arithmetic-scale graph, and lumps 80 cases with dosages from 5,000 to 44,000 rads into a single point plotted at 12,000 rads.

Fourth: the BEIR report notes that the resulting graph is "more consistent with a curvilinear relationship" and that "there appears to be a lower limit of dose at which no significant cancer effects have yet been observed", and yet inconsistently proceeds to extrapolate and to propose for the low-dose domain an "absolute risk" on a linear nonthreshold model.

By introducing arbitrary and dubious assumptions of a quality factor (QF) of 10 and a uniform 40-year burden time for all subjects the BEIR report elects to represent the regrouped data by a linear nonthreshold model with a slope of 0.11 bone sarcomas per year per million person-rems. By removing the assumptions of QF = 10. and burden-time = 40 years, this slope would correspond to a cumulative incidence or occurrence of $4.4 \cdot 10^{-5}$ sarcomas per person-rad. Application of the statistical chi-square test for goodness of fit indicates that differences from this BEIR linear nonthreshold model as large or larger than those observed could be due to chance is less than 1 in 1,000,000 repetitions.

Clearly the BEIR linear nonthreshold model is in violent disagreement with the actual data on humans and is unsupportable, especially in the low-dose domain contemplated in 40CFR190.

Many experimentalists have tried, without success, to find a smooth analytical function which would give an acceptably close fit to the human dose-vs.-response relationship over the entire range of dosage. A breakthrough of extreme importance in the theory of bone cancer induction by alpha-radiation has been made recently by J. H. Marshall and P. G. Groer. They recognized that the usual 2-dimensional dose-vs.-response curves are but cross sections in a multidimensional system involving at least 3 dimensions: tumor rate, dose rate, and time. Marshall and Groer have presented their model (Center for Human Radiobiology. Annual Progress Report to June 1975. ANL-75-60, Part II, pp. 1-38) in terms of a set of 4 differential equations which describe a two-step "initiation" by two separate alpha particles, leading after "promotion" by natural bone remodeling processes to malignancy, with both initiation and promotion operating in competition with cell killing by alpha particles.

The Marshall and Groer model gives for the first time an acceptable fit to the dose-vs.-effect data on mice and dogs as well as the data on humans. For humans, the observed plateau of cumulative incidence vs. dose at average skeletal doses over 1000 rads emerges from this theory, and the cumulative incidence below 1000 rads varies approximately with the square of the dose, distinctly not in a linear fashion. Also the distribution of tumor appearance times with dose level, to be discussed in the following paragraphs, emerges from this same multidimensional model.

Practical Threshold.

Figure 2 shows the relationship observed between the tumor appearance time and the skeletal average cumulative rads (CR) for the 43 radiogenic tumor cases in radium and mesothorium patients studied at M.I.T. between 1934 and May 1969. (Figure 2 is from the same chapter as Figure 1 by Evans, Keane, and Shanahan in the Radiobiology of Plutonium.). The coding of the symptoms for each case is shown on the inset to Figure 2. The 7 tumors which developed between 1959 and 1969 are encircled.

The trend of an increasing elapsed number of years between exposure and tumor appearance with decreasing dose is indicated by the two dotted lines, one through the middle of the distribution and one representing the lower envelope of the distribution. Besides the 43 cases shown in Figure 2, 38 additional cases have now been studied and are included in the Center for Human Radiobiology population (loc. cit.) for a present total of 81 radiogenic tumor cases. All of these additional cases lie above and to the right of the lower envelope dotted line in Figure 2.

The implication of this empirical relationship for human radiobiology is that there is some value of the dosage below which the tumor-appearance time exceeds the life-span. For example, the lower envelope dotted line in Figure 2 suggests that for a skeletal average dose of about 260 rads the tumor appearance time would exceed 100 years.

This leads to the identification of a so-called practical threshold of irradiation where the tumor-appearance time exceeds the life-span remaining after irradiation and hence radiation-

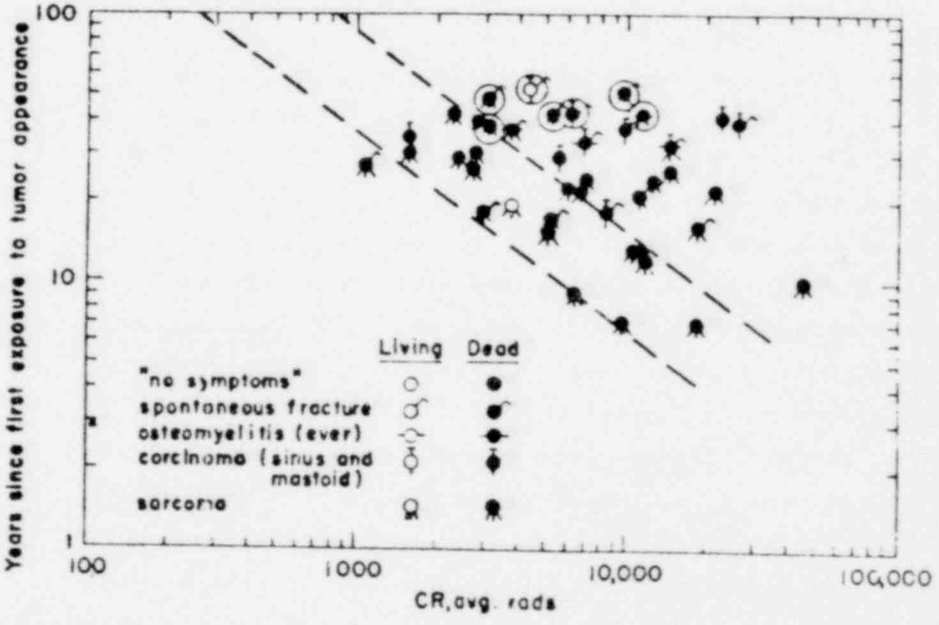

Figure 2. Tumor appearance time vs. skeletal average rads (CR) for 43 human cases studied at M.I.T. Thirty-eight additional cases studied at other laboratories all lie above and to the right of the lower envelope dotted line. From Evans, Keane, and Shanahan (1972).

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induced tumors appear with negligible frequency. This "practical threshold" must not be confused with the common concept of "threshold" or more precisely of an "absolute threshold", which connotes a complete immunity even if the recipient could live to be a 1000 years old. The "practical threshold" concept connotes only a tumor-appearance time which is so long that life ends for other reasons before sufficient time has elapsed for the tumor to develop and appear as a clinical entity.

The increase of tumor appearance time or "latency" with decreasing dose has been shown by Jones and Grendon ("Environmental Factors in the Origin of Cancer and Estimation of the Possible Hazard to Man", Food and Cosmetics Toxicology 13, 251-268 (1975)) to be a general relationship in chemical carcinogenesis as well as radiation carcinogenesis. Hence it is of basic importance in connection with all environmental pollutants. For many carcinogens the latency increases inversely approximately as the square root or cube root of the dose. This implies that both chemical and radiation carcinogenesis involve multi-event initiating phenomena as well as tissue repair and recovery.

It should be pointed out also that thresholds are recognized for other types of high-LET radiation in humans. Of special relevance to uranium mining and milling would be the observation that excess lung cancer among uranium miners in the United States has been shown to occur only at exposure levels in excess of 120 Working Level Months (V. E. Archer, J. K. Wagoner, and F. E. Lundin, Health Physics 25, 351-371 (1973), and Lundin, Wagoner, and Archer, "Radon Daughter Exposure and Respiratory Cancer Quantitative and Temporal Aspects", Joint Monograph No. 1, National Institute for Occupational Safety and Health, and National Institute of Environmental Health Sciences, pp. 8, 111 (1971)). Other recognized threshold phenomena in man include radiation cataract in the case of both low-LET and high-LET radiations (ICRP Publication 14, "Radiosensitivity and Spatial Distribution of Dose", p. 47 (1969)).

Dose-Rate Effects for Alpha Irradiation.

Each data point in Figures 3 and 4 represents an individual human radium case, and by the coding on the data points shows the health status of several hundred exposed persons as a function of years since first exposure and their accumulated radiation dosage. The 198 cases indicated below about 100 CR and 2500 CRY are all symptom-free and are not plotted in order to minimize clutter. (These figures are from the chapter on "Radiogenic Tumors in the Radium and Mesothorium Cases Studied at M.I.T." by R. D. Evans, A. T. Keane, R. J. Kolenkow, W. R. Neal, and M. M. Shanahan in the book Delayed Effects of Bone-Seeking Radionuclides, C. W. Mays, et al. editors, University of Utah Press, 1969).

In Figure 3 the dosage coordinate is skeletal average cumulative rads (CR), as in Figures 1 and 2. In Figure 4 the dosage coordinate is skeletal average cumulative rad years (CRY). The parameter CRY weights each increment of rad dose by the number of years since that increment was received (see R. D. Evans, British Journal of Radiology 39, 881-895 (1966) for details). If there were no cellular repair or tissue recovery from radiation then each element of rad dose would confer a probability of malignancy which would be constant in time and the total risk from that element of rad dose would be proportional to the element's rad-year value. If there is repair or recovery then the risk would be less than the rad-year product.

Note that in Figure 3 where the dosage is in CR units severe injuries and early deaths occur only at higher values of CR, and

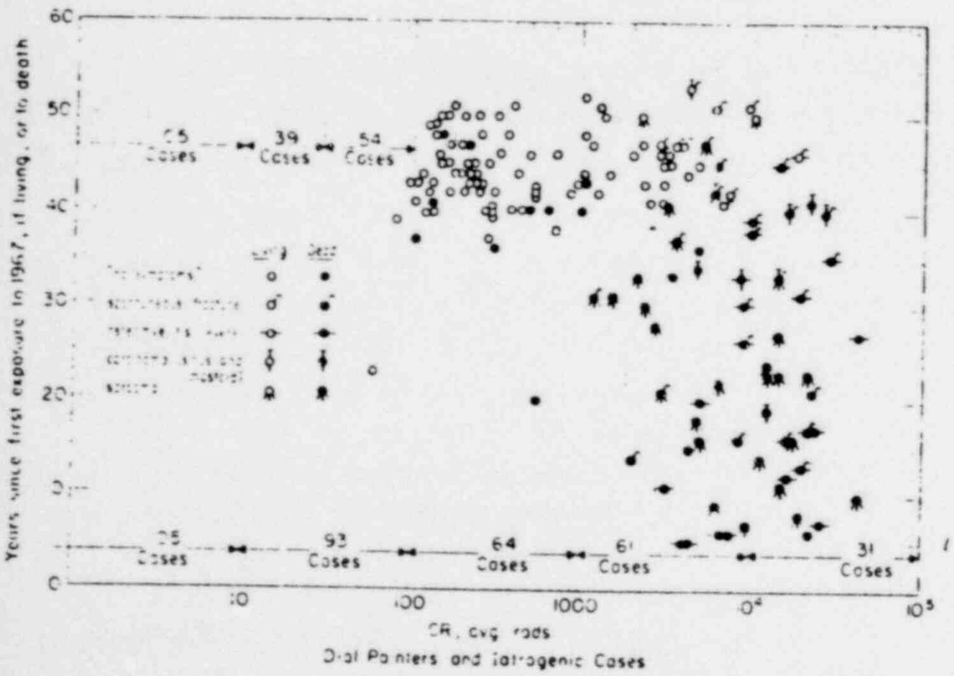

Figure 3. Status of human cases with internal burdens of radium. CR is the average cumulative rad dose to the skeletal tissues. From Evans, Keane, Kolenkow, Neal, and Shanahan (1969).

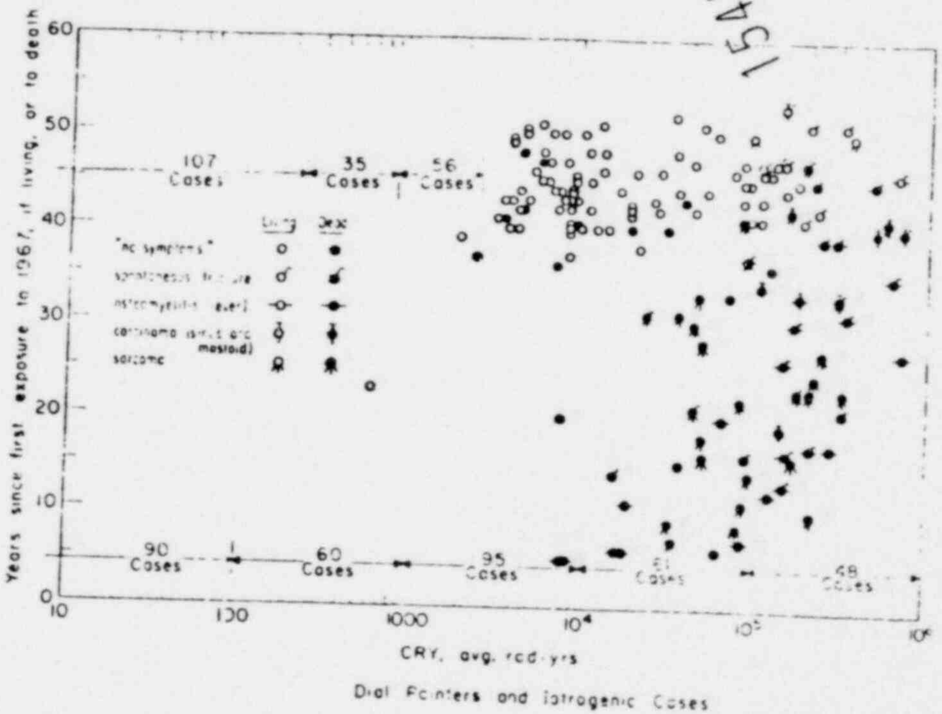

Figure 4. Status of the same human cases as in Figure 3 plotted against dosage in skeletal average cumulative rad-years (CRY). From Evans, Keane, Kolenkow, Neal, and Shanahan (1969).

the pattern involves a general decrease of survival time (years since first exposure) with increasing CR. But note that in Figure 4, where the dosage for the same patients is in CRY units, the distribution of severe injuries and early deaths (lower right-hand portion of the graph) lies in a pattern which has a positive slope. Thus in a dosage domain such as that near CRY = 4 × 10^4 rad · years the median of the survival distribution appears to be double-valued (either about 20 years or greater than 45 years). Members of the lower and severely injured group experienced a high dose rate for a small number of years. Members of the less affected upper group achieved the same CRY dosage at a low dose rate for a large number of years. This double-valued character of the CRY-response distribution indicates that the dosage parameter CRY, which assumes no recovery from alpha-radiation, overemphasizes the influence of time, and that therefore for alpha-radiation from internally deposited radium in humans there is finite tissue recovery and a demonstrable dose-rate effect.

After referring to NCRP Report No. 43, "Review of the Current State of Radiation Protection Philosophy (January 1975), EPA's Supplement B, on page 2 states that:

> "For high LET radiations, such as alpha-particle irradiation due to effluents from the Uranium Fuel Cycle, NCRP seems to accept the use of linear nonthreshold hypothesis"

This implication that "NCRP seems to ..." arises presumably from a loose and inapplicable reading of page 11 of NCRP Report No. 43 which refers only to cell systems, and distinctly not to entire organs or the entire animal or person, as would be realized from the text on page 12 of the report. The experimental evidence in humans shows that there is tissue recovery and a diminution of radiation effectiveness with reduction in dose rate even for high LET radiations.

Dose-Rate Effects for Gamma and Beta Irradiation.

For low LET radiations, such as beta rays and the secondary electrons which are the radiobiologically significant agents produced by gamma rays, the specific new reference which is presented in Supplement B as an argument against the long-accepted ameliorating effect of dose protraction is an unpublished paper by J. Martin Brown, D. Phil., on "Linearity versus Non-linearity of Dose Response for Radiation Carcinogenesis" presented at a Heal Physics Society meeting in Buffalo on July 15, 1975. Dr. Brown kindly supplied me also with a copy of his text. He correctly emphasizes the existence of marked species differences, and states:

> "Clearly, mechanisms important to the induction of some neoplasms in rodents may not be relevant to humans. For this reason great care must be exercised in extrapolating even general principles of radiation carcinogenesis from animals to man."

Yet he discusses animal and cell culture work at some length, as well as reviewing some portions of the radiobiological literature on man. He does not mention the extensive studies of the effects of radium in man. .

Brown undertakes to compare the risk per rad at low and at high dose of low-LET radiation for induction of thyroid carcinoma, leukemia, and breast cancer. The human data he selects for these comparisons are quite incomplete. With respect to thyroid carcinoma Brown's low-dose datum is from the study by Modan et al. of children in Israel whose scalps were treated for ring worm by irradiation with 90 kVp x-rays. (Werner, et al., Phys. Med. Biol. 13, 247-258 (1968); Modan et al., Lancet 1, 277-279 (1974)). Professor Modan and I have discussed these observations in correspondence. An important confounding factor in these studies is the concomitant and very much more intense irradiation of the pituitary. Also 2 of the 12 thyroid tumors found in the study population of about 11,000 children, selected from treatment records on 16,473 children, occurred at 1.5 and less than 1 year after irradiation and may not be radiogenic. Subtracting the 2 cases found in the control group leaves some 8 or at most 10 cases, for which the Poisson standard deviation in occurrence is well in excess of 30%, with 95% confidence limits of more than 60%. The confounding influence of heavy pituitary irradiation and the statistical uncertainties are too large to justify use of these data as the low-dose pivot point in a linear dose-vs.-response hypothesis.

With respect to leukemia induction at low-dose, Brown invokes the limited data of the BEIR report, neglecting the careful and definitive epidemiological study by Saenger, Thoma, and Tompkins (J.A.M.A. 205, 855-862 (1968)) which showed that in 22,000 patients treated with radioactive iodine for hyperthyroidism, the whole body dose of 11 rads, blood dose of 15 rads, and bone marrow dose of 7 to 13 rads does not increase the leukemia incidence. Also, in the only age-specific study of leukemia in the Japanese A-bomb survivors (Ishimaru,et al., Radiation Research 45, 216-233 (1971)) the occurrence of leukemia among persons receiving less than 100 rads of gamma-radiation at Nagasaki shows no excess, and in fact is only about one-half as great as in the control population. The Hiroshima population is not directly relevant because of the large neutron component in the radiation from their bomb. Thus the actual low-dose data on leukemia induction in humans does not support Brown's contention that leukemogensis is as great for low doses as it is at high doses above several hundred rads.

Finally, even if the radiobiological effects of radiation were the same at low dose as at high dose, Brown's reasoning (mss. p. 18) that "then there should be no difference between risk estimates derived from high and low dose rates (emphasis added)" is invalid. A well-known example which negates such reasoning is the mammalian radiation genetics of W. L. Russell et al. (e.g., ORNL Biology Division Annual Report to June 30, 1975, p. 120, et ante) which continues to show that at constant dose rate, radiation mutations are roughly linear with dose, but that at constant dose the mutations decrease markedly with decreasing dose rate, i.e., they are strongly dependent on dose rate.

Thus the emphasis which EPA in Supplement B has put on Brown's paper cannot be supported when the input data and output reasoning are scrutinized. Radiobiological effects of low-LET radiations are dose-rate dependent.

The concensus of informed scientific judgment on dose-rate dependence is well represented by the adoption for health-effect estimates by NRC of a "dose-effectiveness factor" (WASH-1400, Appx. VI, p. G-8) which, at low-LET dose rates of less than 1 rem/day has the value 0.2. Thus a measured dose of 25 mrem/yr could be expected to have a health effect of only 25 × 0.2 = 5 mrem/yr.

Many radiobiological phenomena in humans are known to be dose-rate dependent, and nonlinear with dose. The admonition so often repeated since 1958 that the usual linear nonthreshold model represents an estimate of the upper limit of risk, by UNSCEAR, FRC, ICRP, NCRP (e.g. Report No. 43, p. 4) and BEIR (e.g., p. 88, "the possibility of zero is not excluded by the data") and the existence of relevant data on human exposures should not be overlooked by EPA in its efforts to estimate health effects.

SUPPLEMENT H. RELEASES FROM THE MODEL MILL, LUNG DOSIMETRY, AND ESTIMATED HEALTH EFFECTS

Supplement H is a 35-page heavily revised version of Section 2, pp. 21-74, on Uranium Milling in the EPA's "Environmental Analysis of the Uranium Fuel Cycle. Part I - Fuel Supply" EPA-520/9-73-003-B (Oct. 1973), hereafter called "EA". Pages 57-74 of EA dealt with radon release from tailings piles, contained many inaccurate and misleading statements and implications, and happily is removed from further consideration at present by the exclusion of radon-222 and daughter products from the provisions of the proposed 40CFR190.

Zero Water Release from Mills.

Supplement H removes from consideration all radiation from mill-effluent water pathways by categorically excluding routine liquid discharges, with the justification (p. 15) that:

> "... it is now believed to be standard practice to collect and return any such seepage to the tailings pond so that there are no routine liquid discharges of radionuclides to water pathways from mills."

Experienced environmental control and safety engineers in major uranium-producing companies do not concur. Rather, the concensus is that zero water release is not technically possible using the best available practical technology, even in areas of flat topography and arid climate.

Even if the consumptive use of water by solar evaporation of tailings ponds could be shown to have a favorable cost-effectiveness in a particular arid area, there are other arid areas where local topography prohibits the use of solar evaporation. Also, some

future mill sites may be in non-arid areas of greater precipitation and runoff, making total solar evaporation energetically impossible.

The Highland Mill, whose pre-operational environmental statement seems to have been used as the basis for much of EA Section 2 and Supplement H cannot be used as a universal prototype mill. Differences in local topography, climatic and limnological conditions, population distribution, and other parameters require that every mill be considered separately on a case-by-case basis. For example, mills which serve underground mines have little available overburden for backfilling tailings piles compared with mills which serve open-pit mines.

Supplement H, on page 11, cites the environmental statement for the Highland Mill as assuming a seepage concentration of 350 pCi of Ra-226 per liter. This assumption is grossly discordant with measured values at operating mills. Such concentrations may be found in the tailings pond, but the subsurface seepage at the base of the tailings dam has a measured radium concentration of only about 10 pCi/l, due to the well-known properties of clay and similar soils for intense adsorption of radium. This is another example of the unsuitability of the Highland Mill environmental statement as a prototype for actual field conditions.

If or when the radioactivity of water releases is considered by any regulatory agency, the EPA assumption that humans drink 2 liters of stream or tap water per day (FR, 40, 34324) should be replaced by the much smaller and more realistic values given in ICRP Publication No. 23 on Reference Man which indicate that in the USA tap water accounts for only about 12% of the total daily fluid intake. Also the extensive analytical studies of the radium content of midwestern municipal water supplies in the late 1950's and early 1960's by A. F. Stehney and H. F. Lucas and colleagues of the Argonne National Laboratory and the related epidemiological studies by the U. S. Public Health Service's "Midwest Environmental Health Study" should be carefully reviewed for their considerable content of relevant factual material.

Airborne Releases from Mills and Tailings Piles.

With respect to airborne releases of uranium, radium, and thorium from mills and tailings piles Supplement H contains extensive revisions of Section 2 of EA, mostly downward in release source terms and upward in costs. Even so, experienced environmental control engineers find that in some cases where actual costs are known from industry records the actual costs far exceed the cost estimates given in Supplement H.

The estimates of lung dosimetry depend upon the assumed source release terms, and the meteorological dispersion factor, as well as metabolic and radiological assumptions incorporated in the lung model. Beyond this the conversion of estimated lung doses to health effects contains all the uncertainties and inaccuracies in dose-vs.-response relationships which have already been discussed in connection with Supplement B. Nowhere is sufficient information on the input data and on the details of the meteorological and biological models given to permit an independent test of even the accuracy of the calculations, let alone an appraisal of the validity of the assumptions.

Meteorological Dispersion Factor.

Some semiquantitative comments can be made on the numerical values for the meteorological dispersion factor, $\bar{\chi}/Q$, which are chosen in EA page A-2 et seq. The meteorological dispersion factor is the ratio of the concentration $\bar{\chi}$ of an airborne material at a distance x downstream when the material enters a windstream of velocity U at a height h and a rate Q. Its reasonably well-known mathematical form is that of the product of two Normal Distributions (e.g., R. D. Evans, The Atomic Nucleus, McGraw-Hill (1955), p. 748) with variances c_y^2 in the crosswind direction and c_z^2 in the vertical direction, both evaluated with the aid of meteorological dispersion theory tables for various lapse rates and other atmospheric stability conditions and various distances x downstream. Also $\bar{\chi}/Q$ is inversely proportional to windspeed U.

Nothing in the discussion of the numerical evaluation of the meteorological dispersion factor in Appendix A of EA speaks of what windspeeds were used in the numerical evaluations, nor what site-specific atmospheric stability conditions were assumed. The environments listed in Table A-1 (EA, p. A-3) are for "river", "lakeshore", and "seashore", all of which relate to land/water boundaries where on-shore breezes can occur. No justification is offered for applying these values to arid environments with flat or mountainous topography.

In meteorology it is well recognized that these site-specific parameters are of great importance, and that the meteorological dispersion factor can vary by more than an order of magnitude between morning and afternoon at the same site.

Also no comment is offered with respect to wind direction. From the footnote to Table A-1 (EA, p. A-3) relating to "maximum sector concentration" it seems likely that the values tabulated relate to a "sector", which in meteorology means 1/16 of a circle, or 22.5°. Thus the inference is inescapable that the values of $\bar{\chi}/Q$ used for all the lung dosimetry estimates contemplate a wind of unstated but constant speed, blowing in a constant direction. If so, the subsequent dosimetry would apply only to persons living downwind, while those living outside the downwind sector would receive negligible exposure.

Clearly, from the fragmentary data given for the meteorological dispersion factor, all lung dosimetry calculations as well as health effect estimates have to be taken by the serious reader cum grano salis.

Experimental Basis for Lung Dosimetry.

It seems unrealistic to use such calculated values, mainly from the pre-operational environmental statement for the Highland Mill, as a basis of lung dose estimates. What is needed is actual field data from a number of operating mills. A study of effluent airborne particulates, analogous to the joint AEC/USPHS study by Claude W. Sill and S. D. Shearer, Jr. (Bu. Rad. Health, March 1969) of radon concentrations near actual tailings piles might be considered as a good starting point.

No radiobiological or cost-effectiveness justification is found for the selection in 40CFR190 of 25 mrem/yr as a limitation applicable to the general public as a result of planned or operationally minimized discharges from uranium milling. Twenty-five millirems per year is a very small dose. It is less than cosmic radiation at sea level, and about one-half of the cosmic radiation at 6000 feet elevation. It is less than the normal gamma-ray background in anybody's back yard. It is about the same as the irradiation by natural potassium-40 found in all human muscle tissue, and it is much less than the annual per capita dose of medical x-rays. Whatever the radiobiological effects of 25 mrem/yr, if any, they are miniscule in comparison with the natural occurrence of the same biological or medical endpoints.

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RECOMMENDATION

Because all of the effluent, dispersion, and dosimetry considerations not only contain inaccuracies but are based on uniform hypothetical conditions, and not on actual measurements in the vicinity of operating mills, the American Mining Congress recommends that the proposed 40CFR190 not be made effective.

STATEMENT OF ROGER J. MATTSON

DIRECTOR, DIVISION OF SITING, HEALTH & SAFEGUARDS STANDARDS

U.S. NUCLEAR REGULATORY COMMISSION

PRESENTED BY

EPA HEARING ON PROPOSED 40 CFR PART 190

MARCH 8, 1976

Introduction

I am appearing in this hearing to present a statement on behalf of the Nuclear Regulatory Commission. The Commission has followed closely the development of the proposed 40 CFR Part 190 and has identified two general areas of interest. These are, first, the effectiveness of the proposed standard as an addition to the existing NRC program for regulatory control of radioactive materials in effluents, and second, the practicability of implementation of the proposed standard.

This brief statement today will summarize our views from the perspective of the agency responsible for implementing and enforcing radiation protection standards applicable to the nuclear power industry. Attachment A to this oral statement is a staff analysis which elaborates on the points which I will be addressing and a copy of our previous written comments on the proposed standard. We request that these attachments be incorporated in the record of this proceeding.

The Proposed Standard - An Overview

Our purpose today is to consider the advisability of imposing an additional set of radiation standards on that segment of the nuclear industry that processes and uses uranium for the production of electrical energy. It is important to realize that the nuclear power industry is closely regulated, and has been since it came into being, to provide assurance of the protection of people and the environment.

Under the Atomic Energy Act of 1954, the Atomic Energy Commission developed regulations within which the industry has been required to control its emissions of radioactive materials to levels below the radiation protection limits set on guidance from responsible government agencies with advice from eminent scientific authorities. These regulations contain the criteria to maintain radiation exposures at as low as reasonably achievable (ALARA) levels. The regulations were augmented less than one year ago when the NRC quantified the ALARA criteria contained in the regulations it inherited from AEC so that effluents of radioactive materials from uranium fueled power reactors are but a very small fraction of the existing radiation protection limits. Thus, we are not dealing with a source of pollution that has been allowed to defile the quality of the environment. Rather, we are dealing with a potential source of pollution that always has been required to be controlled before power production operations were allowed to begin. Furthermore, as this power production technology has matured, it has had increasingly stringent effluent guidelines laid on because the responsible regulatory agency made public determinations that lower guidelines practicably could be achieved.

The questions before us then are, "Will the uranium fuel cycle standard proposed by the EPA improve the environmental protection now provided, and, if so, is the improvement worth the additional costs to the consumer which the standard entails?"

I want to make it clear at the outset that the NRC endorses the use of generally applicable environmental radiation standards which we can implement and enforce in the regulation of the nuclear power industry. AEC supported the transfer of the responsibility for such standards to EPA during the development of Reorganization Plan Number 3, and NRC staff has aided technical development efforts in that regard.

While we support the work by EPA on standards for radiation in the general ambient environment, we find that the proposed 40 CFR Part 190 is not an acceptable standard for reasons which we detail below. We view the proposed 40 CFR Part 190 as an unnecessary and costly overlay of the existing NRC program for assuring protection of public health and safety from exposure to low levels of radioactive material released in routine operations of facilities comprising the uranium fuel cycle. In simplest terms, we believe that the public interest would not be served by this proposed addition to the existing regulatory framework.

As we show in this statement and in the attached staff analysis, we believe there has been an incomplete analysis of the costs and benefits of the proposed 40 CFR Part 190. The Draft Environmental Impact Statement is deficient in important areas which are not corrected by the Supplementary Information issued on January 5, 1976. Even with these deficiencies, the partial cost analyses which were performed show that the benefits to be derived from the standard do not justify the costs of its implementation. In this regard, we believe that there has been serious underestimation of the real costs of compliance with the standard and an overestimation of potential benefits which would result. In addition, implementation incident to demonstrating compliance with the proposed 40 CFR Part 190 would require substantial modifications of the existing regulatory system for control of the design, operation, and surveillance of all facilities in the uranium fuel cycle. In addition to the modification of NRC rules, guides, standards and procedures which would be required to implement 40 CFR Part 190, implementation of the standard would potentially require re-examination of more than 120 nuclear facility licensing actions.

The proposed standard would require an implementation system which is counter to accepted and proven past practice for regulatory control of radioactive material in effluents. To understand the long term impact and burden portended by this problem, it is useful to briefly enumerate the principal features of the present NRC program for control of radioactive material in effluents. This program gives emphasis to the design of effluent control systems and operational <u>effluent monitoring</u> and recognizes the extreme difficulty of environmental measurements. By these mechanisms a licensee is required to consider emission controls at an optimum time in the life of a facility, i.e., during its design, and to exercise operational controls at the optimum location; i.e., at the sources of radioactive materials. In addition, our existing system takes maximum advantage of a basic principle of engineering measurements by requiring the measurement of radioactive material at its <u>source</u> or in <u>effluent</u> streams where releases are controlled. At these locations the concentrations of radioactive material are orders of magnitude larger than the concentrations which occur after dilution in the general ambient environment. Further, the low environmental concentrations of man-made radioactive material are usually impossible to discern from the larger and variable radiation levels naturally occurring in the environment.

In contrast, the proposed approach in 40 CFR Part 190 emphasizes <u>environmental</u> monitoring, which, for the extremely low radiation levels of interest here, has been proven to be highly inaccurate even with the most sophisticated measurement devices. The inaccuracy of environmental monitoring for extremely low levels of radioactive materials cannot be remedied by costly development of instrumentation because the low levels of man-made radiation in the environment are small compared to levels of natural radiation. In addition, the inherent variability of climatic and other environmental conditions, including background radiation, seriously detracts from the practicality of using environmental monitoring to demonstrate compliance with the proposed standard.

In addition to requiring substantially more environmental monitoring, implementation of the proposed 40 CFR Part 190 would require shutdown of facilities for noncompliance at emission levels very near those anticipated for normal operating conditions. Variances would be difficult if not impossible to apply in the case of fuel cycle facilities other than reactors and would require the demonstration of a public need for power. This basis for variance ignores larger cost-benefit considerations such as the costs to consumers of more than $250,000 per day for a 1000 MWe nuclear power plant for replacement fuels, such as coal or oil, or the incremental public health effects arising from shutdown of a nuclear plant and replacement with a high emission coal or oil fired plant. Furthermore, the substantially increased environmental monitoring would be required and the economic risks of forced shutdown would be present throughout the operating history of a facility. The long term costs and inefficiencies of this form of regulation are not justified for the proposed standards in view of the lack of any measurable increase in the protection of public health over that afforded by NRC's current regulatory framework.

The Proposed Standard - Specific Concerns

We have three kinds of specific concerns with the proposed standard; first, we believe that the analysis has not correctly assessed radioactive effluent control technology and the practicability of compliance with the proposed standard; second, we believe that the proposed standard would be impracticable to implement for technical and economic reasons for major components of the uranium fuel cycle; and third, we believe that it will be impossible to demonstrate, using environmental monitoring, either compliance or noncompliance at the low levels specified in the standard. We will enumerate these concerns. Supportive elaboration and technical data can be found in the attached staff analysis.

The criteria contained in the proposed standard cannot be traced to the technical analyses in the draft environmental impact statement or supporting documents. The numercial values for the criteria apparently were chosen as arbitrary limits and the feasibility of compliance was rationalized by comparison to effluent control values published by AEC and NRC in connection with the Appendix I rulemaking, in environmental impact statements, and in case-by-case licensing actions. There are two deficiencies in this approach. First the draft EIS provides no cost-benefit basis for the proposed numerical limits for doses to individuals. Thus, the EPA analysis is insufficient to demonstrate the practicability of the proposed standard. Second, some of the AEC and NRC environmental impact statements and licensing data used to rationalize the feasibility of compliance with the numerical limits are now obsolete due to changes in design objectives to reflect issuance of Appendix I, accumulation of more recent operating data, and changes in our calculational models. The calculated doses to individuals as a result of these changes are still small in comparison to the present radiation limits in 10 CFR Part 20, but not small in comparison to the proposed standard. As a result of these changes, it will be more difficult to meet the proposed standard. Therefore, the data derived from AEC and NRC environmental statements are not sufficient to rationalize the practicability of the proposed standard. In summary, there is no basis in practicability for the proposed standard. Thus, there is an inadequate basis for introducing the new and costly operating limits that it contains.

The analysis underlying the proposed standard underestimates the considerable importance of commercial scale operating data in setting radiation limits very near the best expected performance capability of radioactive waste control systems. In the development of Appendix I we learned of the importance of such data in setting ALARA design objectives for light water reactors, which is the only component of the uranium fuel cycle for which adequate commercial operating data and experience exist for setting generic ALARA guidance. Despite the demonstrated nature of LWR effluent controls, our Appendix I numerical guidelines increased twice in the course of the rulemaking to account for changes in practicability assessments as more operating data became available.

By contrast, the proposed radiation limits, as they would apply to reprocessing plants and to tailings piles at operating uranium mills, have no basis in commercial scale operating data. There simply are insufficient data from which to judge the feasibility of the proposed standard. Since no cost/benefit basis has been provided for the selection of the numerical values, we must conclude that there is a high risk that compliance with the standard also would be impracticable for uranium mills and reprocessing plants. The Nuclear Regulatory Commission is, in fact, currently considering a staff recommendation to postpone rulemaking for generic ALARA numerical guidance for fuel cycle facilities other than reactors, due to the lack of commercial scale data. Furthermore, since the proposed standard does not allow for variance in the event of demonstrated impracticability on a case-by-case basis, implementation of the standard would create a high financial risk in the allocation of corporate resources to fuel cycle facilities because of the uncertain risk of shutdown of those facilities.

One of the important elements of the proposed standard - the limit on quantities of certain long-lived materials entering the general environment in proposed Section 190.10(b)--is not a generally applicable standard when considered along with the variance provisions of proposed Section 190.11. Considered together, these sections contemplate limits on quantities of certain radioactive materials entering the environment which are dependent on both the number and size of nuclear power reactors and the particular circumstances that may be applicable to individual nuclear facilities. We believe that such a case-specific limit is not within the scope of EPA's authority under Reorganization Plan Number 3. Fuel reprocessing plants are the dominant source of these materials, so that the proposed standard will, in practice, be an effluent limit for these facilities.

The EPA has not correctly interpreted the practicability implications of NRC's final decision on Appendix I of 10 CFR Part 50 for light water reactors. We have elaborated on this point previously and we do so again in the attached staff analysis. Apparently the largest source of continued misunderstanding lies in the need to recognize that Appendix I allows designers of multi-unit LWR sites to select different radioactive waste treatment equipment for each reactor unit. For example, we would expect a multiple unit LWR station to operation, on occasions, at several times the Appendix I design objective values for a single reactor unit. This concept leads to doses to individuals which are small compared to current radiation protection limits, but doses that could be in excess of the proposed 40 CFR Part 190. Since Appendix I presents the considered practicability judgments of the NRC, we continue to underscore the conclusion that the proposed 40 CFR Part 190 is impracticable for stations having more than two large LWRs.

In the staff analysis we have provided considerable elaboration on other specific technical points. These include: 1) recent information on PWR fuel leakage rates and primary to secondary leakage in steam generators; 2) recent changes in NRC calculations of source terms for licensing actions; 3) specific points in critical review of the cost-effectiveness analysis; 4) an analysis of the cost-effectiveness of Kr-85 capture technology; 5) technical qualification of the ORNL reports written for NRC to characterize fuel cycle facility effluent control technology and cited in the EPA Supplementary Information; 6) an indication of the presently unavailable information which is prerequisite to specific generic controls on tailings piles for operating uranium mills; 7) a summary view of the technology for environmental monitoring and 8) an examination of the need for changes in standards at this time. The staff analysis also contains an elaboration of the procedural difficulties associated with implementation of the proposed standard which we have already summarized. Time does not allow for elaboration here of these somewhat complex and detailed concerns. They are, however, important parts of the basis for our judgment that, on balance, the proposed standard is not generally applicable, is not practicable, is costly, and is an unnecessary overlay of the existing NRC program which regulates quantities of radioactive material in effluents from uranium fuel cycle facilities to extremely low levels.

This hearing panel is familiar with the existing NRC program for control of radioactive material in effluents, and we will not take valuable time to discuss its principal features. A brief summary is provided as Attachment B to this testimony for completeness.

Recommendations

We have stated our support, in principle, for generally applicable radiation standards for the ambient environment. We have also shown why the NRC recommends that the proposed 40 CFR Part 190 not be issued in effective form.

We have reexamined the statutory authorities and the expert recommendations of the NCRP, NAS, and FRC which underlie EPA's responsibilities. The material studied in this review is discussed in the attached staff analysis. We concluded from this review that generally applicable standards are desirable, and revisions of such standards should be based on considerations of the following:

1) the expenditure by society of large resources to reduce radiation risks further than the levels at which they are presently controlled at the expense of greater risks to society that may go unattended; [For example, we need to know what resources should be required for controlling risks from the uranium fuel cycle so that balanced health

and safety protection is provided against all hazardous pollutants arising from the production of electrical energy. The BEIR Committee of the National Academy of Sciences also has identified this need in its 1972 report.]

2) justification of radiation limits, standards, or guidelines on a cost/benefit basis to ensure even-handedness and uniformity in application of national resources to abatement of radioactive and other environmental pollutants;

3) assessments of the broad questions of acceptability of risk; [The BEIR Committee also has identified this need. Because of a lack of Federal policy guidance from EPA in this area, the NRC has proceeded to establish a precendent by ordering rulemaking proceedings to formulate an acceptable monetary value for the worth of population exposure reductions.]

4) development of broad methodology for cost/benefit analysis for all pollutants so that radiation limits for the general population can be based on balanced choices concerning acceptability of risks; allocation of national resources; and the use of uncertain, potentially highly conservative, health indicators such as the linear, nonthreshold radiation dose-effects hypothesis;

5) more definitive operating data from commercial uranium fuel cycle facilities to more completely characterize the interaction of these very low levels of radioactive material with man and the environment and to further improve and validate the realism of calculational models for more efficient regulation of radioactive materials in effluents; [The EPA has recently exercised needed leadership in this regard by initiating, under its FRC authorities, a comprehensive annual report on radiation control in the United States. The NRC is cooperating fully in providing its input to this broad intergovernmental effort. Also, EPA and NRC staffs jointly are giving increased attention to efficient use of monitoring data for model verification.] and

6) the need for timely initiation of international discussions on krypton control.

In closing, the NRC believes that the proposed standard should not be issued in effective form. That does not mean that the considerable effort expended in its development has not been worthwhile. EPA's work has forced critical re-evaluations of the existing NRC program, of industry's performance, and of the nation's needs. It is only because of these critical re-evaluations that we can recommend today with conviction that the presently proposed standard is not needed. And we are able to identify what more is needed, as explained above.

The re-evaluations also have served to identify the need for increased cooperative efforts by EPA, NRC, ERDA, and the power production industry to obtain commercial scale operating data (1) to more realistically characterize the environmental impact of nuclear operations at these very low levels of radiation, (2) to develop and validate more realistic predictive models, and (3) to provide the data base necessary for future reconsideration of generally applicable standards. The NRC is prepared to renew its active support of the Environmental Protection Agency in addressing the considerations outlined above.

We thank you for the opportunity of appearing in this hearing to present the NRC's additional views on the proposed standards. If the hearing panel has questions, we are prepared to respond.

ATTACHMENT A

NRC SUPPLEMENTARY ANALYSIS
OF THE PROPOSED 40 CFR PART 190

MARCH 8, 1976

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I. LIGHT WATER COOLED NUCLEAR POWER REACTORS

II. OTHER FACILITIES IN THE URANIUM FUEL CYCLE

INTRODUCTION

The Nuclear Regulatory Commission (NRC) staff submitted written comments on the proposed EPA regulation 40 CFR Part 190 on September 15, 1975. A copy of these previous comments is attached. In our comments we identified several technical and administrative issues which should be resolved. We have reviewed the Supplementary Information dated January 5, 1976 in which EPA addressed some of the same issues raised in our previous written comments. This supplemental information has not altered our view that the proposed EPA standard (1) would provide little, if any, additional benefit beyond that provided by current regulatory practices, (2) would impose substantial additional regulatory burden, and (3) could prove to be impracticable in compliance by major components of the uranium fuel cycle.

We note in the Supplementary Information it is concluded that Appendix I to 10 CFR Part 50 provides "adequate assurance," prior to operation, that a light water cooled nuclear power reactor (LWR) facility is capable of compliance with the proposed standards for sites containing as many as five reactors but a substantial number of rules, guides, and other licensing procedures would have to be altered to be consistent with the proposed standard. We will address these and other aspects of the practicability and feasibility of implementing and demonstrating compliance with the proposed standard.

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I. LIGHT WATER COOLED NUCLEAR POWER REACTORS

A. Experience Gained from 10 CFR Part 50, Appendix I Rulemaking.

In the Appendix I rulemaking proceeding, some important regulatory experience was gained which we believe can be helpful in the present standard setting effort.

Appendix I of 10 CFR Part 50 establishes numerical guidelines for meeting the "as low as reasonably achievable" (ALARA) criterion for levels of radioactive material in effluents of light water cooled nuclear power reactors. Appendix I was promulgated after an extensive rulemaking proceeding extending over a period of about four years, including an evidentiary public hearing.

The AEC, in initiating the rulemaking effort to specify numerical guidelines which would satisfy the "as low as reasonably achievable" (ALARA) criteria in 10 CFR Parts 20 and 50, faced a situation similar to the one EPA now faces. Light water cooled nuclear power reactors were selected for the initial effort at quantifying the ALARA criteria, not because the reactors were identified as a dominant source of exposures, but rather because commercial-scale power reactors had been operating for more than a decade and a substantial amount of experience and data were available. These data were thought to be adequate to provide a sound technical base for selecting practicable numerical guidelines which would be generally applicable to commercial-scale power reactors.

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The data from effluent measurements by licensees prior to 1971 and other sources were reviewed to select representative values for the "source terms" (quantity and identity of radionuclides in effluents). The source terms were used in analytical models to estimate potential doses to individuals and to populations in the vicinity of nuclear power reactor sites. The numerical guidelines which were derived in this manner in 1971 were thought to represent "good demonstrated engineering practice." Subsequently, in 1973, in developing information for the Environmental Impact Statement for the Appendix I rulemaking proceedings (particularly for the cost-benefit analysis), it was necessary to relate source terms to specific station design features and operating modes. In doing this, it was realized that the existing data on source terms were adequate to demonstrate compliance with the Federal Radiation Councils' radiation protection guides (RPGs)* embodied in 10 CFR Part 20, but inadequate to provide a basis for selecting numerical guidelines substantially below the radiation protection guides. Indeed, minor pathways for release of radioactive material from the LWR stations were identified which previously had not been monitored at all.

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*Radiation Protection Guides for individuals and for suitable samples of exposed groups in the general population were presented by the Federal Radiation Council in Report No. 1 (May 1960) and Report No. 2 (September 1961). The RPG values are:

Population:

Individuals	0.5 rem/yr to whole body 1.5 rem/yr to thyroid gland 0.003 microgram Ra-226 in skelton
Average for population	5 rem/30 years to gonads
Average for suitable sample of exposed group in general population	0.5 rem/yr to thyroid gland 0.001 micrograms Ra-226 in skelton

While these pathways yielded small fractions of dose relative to the higher levels of radiation protection guides, they were substantial contributors relative to the lower ALARA levels.

In summary, as we gained experience in our study of LWR source terms and equipment capability in operation, we concluded that some features of the numerical guidelines proposed in 1971 could not practicably be achieved.

In recognition of this finding, the proposed guidelines were revised to higher values. More importantly, we then first recognized that rather than simply reflecting contemporary "good engineering practices," the values were in part, based on the use of extensive and untested station design features. That is, these unproven features would have to perform as designed in order for LWR stations to achieve compliance with the higher numerical guideline values proposed in 1974. The regulation (Appendix I of 10 CFR Part 50), which became effective on June 4, 1975, is an even further relaxation of the numerical guidelines that were proposed in 1974, partially because it reflects the recognized uncertainties in source terms owing to the lack of data from operating commercial power stations with advanced design features.

We believe it is important that recognition be given to the fact that an adequate technical data base is required for selecting the limit values in 40 CFR Part 190, if the limits practicably are to be achievable. The lessons learned in developing Appendix I concerning the practicability and feasibility of effluent controls imply that the proposed 40 CFR Part 190 is impracticable for those portions of the uranium fuel cycle in which undemonstrated effluent controls must be used to meet the proposed standard.

B. Graded Scale of Action (design objective values) vs. Limits.

"Design objective quantities" and "limiting conditions of operation," which are specified in Appendix I, represent a graded scale of action rather than a limit. The design objective quantities may be thought of as goals which NRC believes can and should be attained in the design and operation of LWR stations. This regulatory concept recognizes that there are many variable factors which affect the ability of a licensee to meet the goals and that there will be occasions when the design objective quantities may be exceeded even though every reasonable measure is being taken to keep effluent levels as low as reasonably achievable.

In contrast, the values presented in the EPA proposed standard are limits.* The proposed standard, in EPA's view, if promulgated, would supersede for uranium fuel cycle facilities the current Standards for Protection Against Radiation, 10 CFR Part 20, which derive from RPGs promulgated by the Federal Radiation Council under Presidential authority [Supplementary Information, Part A, p. 3]. Historically, compliance with RPGs has been demonstrated by restricting potential exposures to levels well below the limiting values and by requiring only sufficient monitoring to verify that potential exposures were well below the limits. This has been done as a practical matter because if the operation of a nuclear facility were such that potential doses could be very near the limits, additional and costly monitoring and surveillance programs would be required to assure that the limits are not exceeded. If the limit is lowered to about 1/20 of the current RPGs, as proposed by EPA, it be impractical to

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*The standard does provide that a "variance" can be granted by NRC for unusual and temporary conditions if it is the public interest to do so. We will discuss this feature of the proposed standard in several sections below.

demonstrate compliance by restricting releases to a small fraction of the lowered limits and it will be necessary to require substantially expanded monitoring and surveillance programs. We further discuss the demonstration of compliance with the proposed standard in Section V.

C. Reactor vs. Site Limits.

In the Supplementary Information dated January 5, 1976, it is stated that the NRC has issued guidance for single LWRs [Supplementary Information, Part A, p. 2] and concludes that it is unlikely that doses from each of several reactors sharing a common site would be additive. [Supplementary Information, Part C, p. 15] This conclusion is wrong.

Appendix I of 10 CFR Part 50 presents numerical guidelines for each light water cooled nuclear reactor. When multiple reactors are placed on one site, the calculated potential doses at a location beyond the site boundary could be only slightly greater than the calculated dose for a single reactor on the site, but there is no such regulatory requirement. Rather, for substantial periods of time the potential doses at that location is expected to be several times greater than the potential dose value for a single reactor on the site. The practicability conclusions of Appendix I are very specific in permitting this. It is important to recognize that if several reactors are located on a site, the individual reactors can (and probably will) have specific design features which differ from the others sharing the site. They may have been designed and built at different times, or reactors which are located more distant than others from a limiting dose receptor offsite may need less radwaste processing equipment in order to meet the criteria of Appendix I. Further, it is common practice for two reactors to share common radwaste systems and effluent release locations. Thus, isodose lines for each of the reactors on the site could intersect or overlap and the potential doses *can* and probably will be additive. If each of the several reactors sharing a single site had *identical* design features, it would be *less likely* that the potential doses from the several reactors would add in a manner to be substantially greater than the potential dose from a single reactor, but even then it *could* occur, and it is not prohibited by Appendix I.

We stated in our previous written comments that three reactors operating within the design objective values of Appendix I on a single site could exceed the limits of the proposed standard. That is, they would be designed to meet Appendix I which is equivalent to design criteria which would permit violation of 40 CFR Part 190 as proposed. Since limiting conditions of operations are twice the design objective values, two reactors on a single site also could exceed the proposed standard. Thus, we cannot agree with the conclusion that Appendix I would provide *de facto* assurance that as many as *five* reactors on a single site would comply with the proposed standard. [Supplementary Information, Part A, p. 4] While we agree philosophically that it would require combinations of liquid and air pathways of exposure which could be simultaneously intercepted by real individuals for the proposed standards to be exceeded at a site containing several reactors, we believe that the *potential* for this combination could arise whenever two or more reactors are evaluated for a single site and NRC would be required to demonstrate that the combination will not occur. It is reasonable to expect that new procedures would be required for LWRs to demonstrate, at the licensing review stage, reasonable assurance of compliance in operation with 40 CFR Part 190.

Appendix I numerical guidelines are applied by calculating the potential doses which might be received by individuals at various locations. They also are applied to potential land and water usage and food pathways which could exist near the site. EPA has stressed that the dose limits in its proposed standard are actual doses to real people. While we believe that it is proper for the standard to be so qualified, it also must be recognized that it is not practical to accurately determine actual doses to real people when there are many variable factors which can affect the doses actually received. Many of these variables cannot be controlled or determined, and there is no practical way to directly measure the doses to an individual from all pathways of exposure.

Thus, dose estimate must be based on analytical models and a considerable range of uncertainty always will be inherent in establishing a relationship between the estimated potential doses to individuals and "actual" doses they receive. As we develop more "realistic" models, the calculated doses will sometimes underestimate the actual doses owing to the variable nature of the parametric values.

Generally, anticipated potential land and water uses are taken into consideration in selecting station design features. While the consideration of potential land and water use in licensing procedures tends to introduce an element of conservatism, this is not necessarily the case over the lifetime of the station.

EPA places considerable reliance on the Commission's statement in its Statement of Considerations for Appendix I that several LWRs on a single site can operate with doses to individuals less than 5% of the present 10 CFR Part 20 limit; i.e., presumably 25 mrem/yr to the whole body as 5% of the 500 mrem/yr limit [Supplementary Information, Part C, p. 3]. It should be noted that the quoted statement of the NRC is not part of the regulation, Appendix I to 10 CFR Part 50. While the values so quoted may be appropriate for multi-LWR sites on the average, the limiting conditions for operation in the regulation permit operation at twice the design objective values and radiation sources other than effluents are not included in Appendix I (e.g., N-16, storage sources, etc.). The sum of all dose contributions at a multiple reactor site can, and probably will, exceed 5% of the current RPGs.

This misunderstanding of the way Appendix I works in practice is amplified when one realizes the added difference between yearly average performance and short term field measurements required by EPA to demonstrate noncompliance with the proposed 40 CFR Part 190 (see Section V, below.)

D. Prospective vs. Retrospective Dose Estimates.

EPA suggests that NRC licensing actions for LWR stations "...should be limited to a finding, either for specific sites or on a generic basis, as appropriate, that the facility has been provided or has available to it adequate means to provide reasonable assurance that these standards can be satisfied during actual operations" [Supplementary Information, Part A, p.4]. EPA suggests that compliance with Appendix I should provide the reasonable assurance of compliance. But nowhere on the record of this proceeding has that conclusion been supported. It is arbitrary. We find substantial differences between Appendix I and the proposed standard and we cannot agree that there now exists a technical basis for concluding that meeting the criteria of Appendix I would necessarily provide reasonable assurance of compliance with the proposed standard.

NRC licensing of nuclear facilities requires a finding that the facility can be operated in a manner such that it can comply with all applicable laws and regulations. As the licensing process procedes from early stages of site selection through construction permit, and to full operating license, the <u>station design</u> develops from general concepts, to general design features, to specific design features, to actual equipment and layout. At each licensing stage, evaluations by NRC are required before proceeding to the next stage. The bases for these evaluations must be made known, and the decisions defended. If the proposed standard is promulgated, NRC also will be required to make findings concerning the capability of the facility to comply with 40 CFR Part 190, before any operating data are available, and to defend these findings. In lieu of specific operating data, it is difficult to defend other than conservative extrapolations of the available data. Faced with uncertainty in projected station operating characteristics, it is likely that the licensee would be faced with either including additional design features (e.g., augmented radwaste systems) in the original station design or to add these features subsequent to startup (at substantial cost penalties) if necessary to comply with 40 CFR Part 190.

Should NRC adopt the EPA suggestion that compliance with Appendix I is reasonable assurance that the facility can comply with 40 CFR Part 190 (given some as yet undeveloped basis for such assurance), the licensee still would be required to either <u>gamble</u> that augmented systems will not have to be added at a later date (backfit) <u>or add</u> these features as part of the original station construction simply because the EPA standard provided limits for operation and not a graded scale of action as provided in Appendix I. Experience has shown that "backfitting" costs frequently range up to <u>several times</u> the cost of original installation. Further, costly "down time" could be required for backfitting. Given replacement power costs for fossil fired plants which range from $250,000 to $2,000,000 per day (depending on local air quality standards and availability of fuels), there are substantial financial uncertainties for the consumers associated with this aspect of the proposed standard.

E. Practicability of Compliance.

Compliance with the proposed standard is impracticable. We have identified several technical deficiencies in the development of information on the practicability of the proposed standard which partially account for this. With respect to LWR stations, EPA cites (1) the report EPA 52019-73-003C, Environmental Analysis of the Uranium Fuel Cycle, Part II-Nuclear Power Reactors, (2) AEC and NRC Environmental Impact Statements for various LWR stations, (3) the Concluding Statement of Position of the AEC staff on Appendix I, and (4) "Conservative" evaluations by NRC staff in licensing proceedings as demonstrating the practicability of compliance. These are insufficient bases for a finding of practicability for compliance with the proposed standard for the following reasons.

1. EPA Report on Reactors

The EPA report 52019-73-003C (Reactors) contains calculated potential dose values based on source terms similar to those used by AEC in 1972 but different from those experienced by licensees in practice and used by NRC in licensing today. Using our current source term estimates, the potential doses calculated by EPA generally would be higher.

It is instructive to review some of the principal changes which NRC has made in the analytical procedures for estimating source terms and doses since February 1974. These principal changes are:

(a) Added procedures for calculating releases of particulates, carbon-14, argon-41, and gaseous tritium releases;

(b) Revised procedures for calculating the liquid effluent releases due to anticipated operational occurrences;

(c) Revised calculational models for containment purge to account for plant operating experience;

(d) Revised calculation of the I-131 releases from BWR ventilation system exhausts as shown below; and

Source of I-131	Old Rate (Ci/yr)	New Rate (Ci/yr)
Turbine Bldg.	0.34	0.19
Reactor Bldg.	0.01	0.17
Auxiliary Bldg.	none	0.17
Radwaste Bldg.	negligible	0.046
Mechanical Vacuum Pumps	negligible	0.03
Total	0.35	0.61

(e) In addition to the source term changes, dose calculations for intermittent releases are based on short term meteorologic dispersion rather than annual average dispersion factors.

Further, organ doses from radioactive material in gaseous effluents are now summed for all pathways of exposure.

Generally, the revisions have resulted in increased calculated releases and, in some cases, in increased calculated dose values. Item (d) is of special interest in that the total release has been increased and the source is from several buildings rather than essentially from one building. This requires more radwaste equipment for the several buildings to reach the same level of control of releases and potentially reduces the overall cost-effectiveness of the augmented treatment systems. This affect is not accounted for in the cost-effectiveness analysis for the proposed 40 CFR Part 190.

2. NRC Environmental Impact Statements

NRC Environmental Impact Statements (EIS) are intended to realistically portray the anticipated effects of nuclear facility operations. The EIS projections are based on the best design information available at the time they are written, which is in advance of plant operation. Therefore, the calculated dose information is not the definitive operating data necessary to judge compliance with a standard set at levels very near the anticipated operating levels. Some of the EIS written a year or more ago contain information which differs from the information which would be contained in an EIS written today. And on the basis of this obsolete information, EPA finds evidence that it will be feasible and practicable to implement limits at or below the level of practicability. The EPA, in fact, does not rely on EIS data for determining compliance. Rather, it is required that actual environmental measurements be used for verification of noncompliance.

Table 1, Part C, p. 5 of the Supplementary Information, is cited as evidence supporting the conclusion that "as many as five LWRs would result in individual exposures that are appreciably less than 25 mrem/yr to the whole body and 75 mrem/yr to the thyroid." Table 1 contains selected information from EIS for three and four unit LWR stations for which EIS were written between 1972 and 1975. (The table should be corrected to indicate that WPPS is not a four unit site, but two units each on two different sites.) The table is an incorrect basis for this conclusion because:

a. When these EIS were written, it generally was assumed that the station design features would be those required to satisfy the AEC staff's proposed numerical guidelines for effluents, i.e., 15 mrem annual thyroid dose at the site boundary for the *combined* operations on the site. (Recall that AEC staff had proposed numerical guidelines in 1971 and 1974). The NRC promulgated Appendix I on May 5, 1975, and it contains numerical guidelines which differ from the previously proposed guidelines in the magnitude of the values selected and in the sense that they apply to *each* reactor on the site rather than *all* reactors on the site. Consequently, licenses for multi-unit LWR stations which had committed to provide augmented radwaste features have the option of *reconsidering* those commitments in view of the present numerical guidelines which generally require less radwaste features than previously proposed guidelines; i.e., utilities may omit those features not required to satisfy Appendix I. Thus the dose values presented in EPA's Table 1 likely would be higher if evaluated today owing to differences between the proposed Appendix I numerical guidelines and the final Appendix I guidelines which were higher for practicability reasons.

b. The doses shown in EPA's Table 1 are based on calculational models that will not be capable of verification for several years when reactors of this size with these design features are operating. For PWRs, in particular, there is little operating data to support the realism of the source term calculational models. Further, the provisions of Appendix I require the use of analytical models which will not substantially underestimate exposure of an individual. In the future, as uncertainties in operating performance decrease, data will feedback on calculational models and the calculated and actual doses to individuals are expected to become equal. Said another way, NRC fully expects future stations to operate very near the design objective release rates specified in Appendix I. EPA's Supplementary Information shows convincingly that EPA has misunderstood this aspect of the practicability of the proposed 40 CFR Part 190.

In actuality, the analytical models and the selected parametric values which are used to estimate source terms and to calculate doses have been undergoing frequent review and modification since they were presented in the Appendix I Environmental Impact Statement (1973). The net effect of these changes in some cases has been to increase the calculated dose values for individuals near the site boundary. The dose values have not been recalculated for those stations listed in EPA's Table 1 because generally these stations are between the construction permit and operating license stages. However, the calculated dose values for other stations, for which EISs were issued a year ago, have now been recalculated. Some of the dose values increase, others decrease. For the cases where doses have been recalculated, thyroid dose values have increased over a range of 2 to 20. Thus, the dose values presented in EPA's Table 1 likely would be higher if evaluated today owing to differences in analytical models used to quantify dose calculations based on new reactor operating data.

c. Reactor operations are not controlled by the estimated dose values presented in the EIS. Rather, reactors are operated in accordance with the technical specifications which are a condition of, and contained in, the station operating license. The limiting conditions of operations are expressed in terms of two release rates: (1) the instantaneous release which, if continued for a year, would result in 10 CFR Part 20 Appendix B limiting concentration values or limiting annual doses offsite and (2) the release which averaged over one calendar quarter would result in calculated doses equal to half the (annual) design objective dose values of Appendix I to 10 CFR Part 50. The dose values presented in the EIS for the station are calculated based on the assumed full time operation of radwaste equipment. Redundancy generally is not required and, if the equipment is not operable for any reason, higher dose values than those presented in the EIS can be anticipated. Again, because of these factors doses higher than those presented in EPA's Table 1 can be anticipated but the magnitude of the doses from operating stations is now known only from calculations; only a few of these calculations have been completed subsequent to the promulgation of Appendix I; and all such calculations have yet to be verified by operational effluent monitoring.

3. Appendix I Concluding Statement

The AEC Staff Concluding Statement* in the Appendix I rulemaking contained a table which indicated that most of the reactors licensed at that time either could comply with the proposed (1974) numerical guidelines or had commited to augment existing systems to comply. However, recent revisions of analytical models used to estimate source terms have invalidated those conclusions. Further, the difference between the

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*Concluding Statement of Position of the Regulatory staff. Public Rulemaking Hearing on: Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion "As Low As Practicable" for Radioactive Material in Effluents of Light Water Cooled Nuclear Power Reactors. February 20, 1974, Docket No. RM-50-2.

proposed (1974) numerical guidelines and the final version of Appendix I is another complicating factor. It is now required to reach a determination of cost-effectiveness and to establish design objective values for *each* reactor. Further, as stated in Section E.2.a. above, licensees may omit those radwaste features not required to satisfy Appendix I. Consequently, the 1974 AEC Staff's Concluding Statement is not now a valid basis for conclusions concerning capabilities of stations to meet the proposed 40 CFR 190.

4. Conservatism

"Conservatism" in NRC licensing analyses have been cited by EPA in several references. EPA uses its conclusions in this regard to substantiate the claim that real doses to real people will likely be less than 40 CFR Part 190 limits for stations licensed under current NRC practice. This conclusion is in error. Our comments on the specific factors identified as contributors to the conservatism are given below.

a. Predicted Dispersion and Deposition vs Measured Values.

Several NRC/EPA cooperative efforts have been made to characterize the dispersion and deposition of radioactive material in the environs around nuclear facilities. While these studies have been instructive, and have provided the most comprehensive data available today, they have been limited in scope and duration and the analyses have *not* provided definitive information which would permit substantial modifications of current analytical models. EPA cites these measurements as showing conservatism in current models but the results are variable - sometimes indicating values higher *or* lower than the predicted values. These results are not suprising, given the uncertainties inherent in the selection of parametric values, in-put data, sampling and analytical procedures, limitations of analytical models, and our attempts to provide realistic estimates. Consider the information presented in the table on page 7 in Section C of the Supplementary Information. The stations at which the measurements were made are not representative of new stations, and the data are not representative and would not be generally applicable because:

(1) Dresden 1 is a unique reactor featuring an indirect cycle BWR and a tall stack for diluting and dispersing effluents;

(2) Yankee Rowe and Haddam Neck reactors employ stainless steel fuel rods which, experience has shown, have lower fuel defect levels than Zircaloy clad fuel. Zircaloy is used in all large LWR stations in the U.S.; and

(3) all three of the nuclear power reactors cited by EPA are small units (ranging from 600 to 1825 MWt) relative to contemporary 3800 MWt reactors.

Further, NRC reviews of EPA reports on the field studies have identified specific technical problems which characterize our concern that the results of specific measurements have been incorrectly generalized from atypical facilities. For example, we sent the following letter to one of the authors of the EPA report on the Haddam Neck field measurements. (The letter is retyped here for convenience of presentation.)

Mr. Bernd Kahn, Director
Environmental Resources Center
Georgia Institute of Technology
205 Old Civil Engineering Building
Atlanta, Georgia 30332

December 17, 1975

Dear Bernd:

Thank you for the opportunity to comment on the report of the EPA radiological surveillance study at Haddam Neck. The report contains much useful information that we will consider in future revisions to our source term calculational models. We believe that measurements of the type you have made, when performed at a number of plants under a variety of operating conditions, provide the most valuable type of data for improving our models. Care must be taken, however, in comparing measurements made at a single plant over a period of a few months, with a calculational model that represents the 30-year operating life of the plant. Also, the measurements need to be related to the plant operating conditions and to plant activities, such as maintenance and operation of certain pieces of equipment, during, and for the period prior to, each set of measurements. In view of the many variables involved, we consider that the measured releases, which in many instances are within a factor of two of the calculated source terms in the staff's Environmental Statement, show excellent agreement with our calculational models.

In regard to your specific question about the apparent inconsistency in the applicant's reported primary to secondary leak rate and the measured releases from the main condenser air ejector, we note that your measured release rate (Table 3.5) is approximately a factor of 2.5 times higher than that reported by the licensee during the same period. The applicant's reported releases imply a primary to secondary leakage rate of approximately 300 kg/hr, which is consistent with the value you report in Appendix C.3 for measurements made on March 16, 1971. We also note that, although both the primary coolant concentration and the primary to secondary leakage rate were steadily increasing during the sampling period, your measured release rates at the air ejector were constant to within ±25%. These facts lead us to conclude that the gas samples taken from the main condenser air ejector exhaust by the EPA may not be representative of true system steady state operation. Such a situation might occur due to the relatively small volume of the samples (1.8 liters) and due to the fact that samples were taken during or shortly following changes in power level, e.g., the July 24, 1970 sample was taken shortly after refueling, the September 16, 1970 sample was taken just after a startup, and the four samples in March and April 1971 were taken while the plant power level was decreasing just prior to refueling. It also appears that the applicant's estimate of the primary to secondary leakage rate of 75 to 150 kg/day is low by a factor of two to four.

We have reviewed only the portions of the report having to do with source terms. If you desire comments on the measurements in the environment, you should contact Enrico Conti of the Radiological Assessment Branch, whose Section is responsible for environmental radiological surveillance. We have received the draft of the report on the surveillance studies at Oyster Creek from Dr. Blanchard and will attempt to provide comments on the measurements as they relate to our source term calculations.

Sincerely,

John T. Collins, Chief
Effluent Treatment Systems Branch
Division of Technical Review
Office of Nuclear Reactor Regulation

EPA has cited data from field studies as revealing "significantly lower iodine concentrations in milk than projected by models for the pathway currently used for environmental analysis" [Supplementary Information, Part C, p. 6]. This conclusion is premature. The data from the Quad Cities station have not been fully evaluated. However, there are extended periods during which the iodine concentrations were considerably higher than would have been predicted using current analytical models. The reasons for this are not fully understood at this time. We do not believe that the data from field studies fully demonstrate the conservatism of NRC analytical models. Rather, the data demonstrate that much more information is needed to obtain a full understanding of the complex relationships between the release of radioiodine in various forms and the low level radiation doses that may be received in the environment.

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To demonstrate the extent to which the results of the field measurements have been misapplied to rationalize that the NRC models are conservative and that compliance is practicable, consider the "Maximum Individual Dose" table in the Supplementary Information, Part C, p. 7. The values are presented as annual doses, yet examination of the EPA reports on these studies, e.g., Radiological Surveillance Study at the Haddom Neck PWR Nuclear Power Station [EPA-520/3-74-007], shows that the data were inadequate to determine potential annual doses. The annual dose values presented for the thyroid, bone, and GI (LLI) were not based on measurements in the environment, but were based on calculations using detailed effluent data. Further, the reported annual whole-body dose values were based on measurements of external dose rates (in terms of μR/hr on discrete days which were used to determine the annual dose rates) made inside the site boundary and extrapolated by calculation beyond the boundary. To this was added the calculated whole body dose contributions from effluent data [See p. 117, EPA-520/3-74-C]. Thus, it is inaccurate to characterize these dose rate values as originating from "field studies." Further, EPA conclusions from these studies, such as the paragraph quoted on p. 7, Part C of the Supplementary Information, are not warranted or justified.

b. LWR Source Terms.

The EPA "Supplementary Information" contains, among other things, a discussion of LWR source terms which concludes that the NRC source term characterization for PWR stations are unduly conservative (high).

We believe that this issue is exemplary of the failure to correctly interpret the practicability aspects of the proposed 40 CFR Part 190. That is, the proposed standard is based on an incorrect assessment of effluent control technology. We will further discuss source terms for that reason.

EPA makes the following statements concerning source terms.

(1) "In addition to conservative environmental dose pathway models, radionuclide source term models have generally been conservative. For example, fuel experience for PWRs has been much better than the 0.25% fuel leakage rate now used as a design basis for calculating environmental releases." [Supplementary Information, Part C, p. 10]

Comment The NRC source term models were developed to provide a realistic assessment of releases of radioactive materials contained in liquid and gaseous effluents from nuclear power reactors, averaged over the life of the station. The parameters used in the staff's models are based on data obtained from operating reactors to the greatest extent possible. Where operating data were unavailable or inconclusive, we relied on laboratory data, test data, and judgement. The "fuel leakage" value of 0.25% referenced above has not been used in our model since the spring of 1975. We presently use a value of 0.12% which is based on data provided by Westinghouse. We consider the value presently in use (0.12%) to be representative of zircaloy clad fuel experience to date for PWRs. This change is important. Future PWR radwaste equipment will be selected by using this realistic source term. Thus, "realism" as

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mandated by Appendix I will make it more likely that multi-reactor stations designed and operated within the requirements of Appendix I will exceed the limits of the proposed 40 CFR Part 190.

(2) "A second important consideration with respect to conservatism in source term-models is the fact that, especially for PWRs, effluents are postulated for inplant pathways which require simultaneous levels of degradation of several parameters in order to lead to a postulated release to the environment. For example, effluents from the PWR secondary system (e.g., steam generator blowdown vent or condenser air-ejector exhaust) require the simultaneous existence of a "design basis" fuel leakage and a "design basis" assumed steam generator leakage rate of primary coolant into the secondary coolant. Since the probability of each "standard" assumption is generally significantly less than one, the probability of both occurring at the same time must be smaller than either of the individual probabilities. Thus, if the annual probability of having the "design basis" number of fuel failures is five percent and the probability of having a "design basis" primary to secondary leak is twenty percent, the probability of operating a PWR with "design basis" fuel leakage <u>and</u> primary to secondary leakage is of the order of one percent. In spite of this, light-water-cooled reactors have been evaluated as if these "design basis" conditions occur simultaneously, for periods of time comparable to a year (17)." [Supplementary Information, Part C, p. 11]

<u>Comment</u> As with our parameter for fission product leakage from the fuel, our parameter for primary system to secondary system leakage within the steam generator is based on leakage rates measured at operating reactors. Our current parameter is based on 15 reactor-years of experience and includes periods of essentially "zero" leakage as well as periods of significant leakage. In both cases, fuel leakage and steam generator leakage, the arithmetic average of the available data was used, not "design basis" upper limits as implied by EPA. Again, EPA has not accounted for the practicability and realism considerations mandated by Appendix I.

(3) "Even though the most recent environmental statements employ models specified by regulatory guides which are more realistic than those used in the past, these models are still conservative. Again, in the opinion of the Nuclear Regulatory Commission on Appendix I on 10 CFR 50 (4):

> "It must be understood in discussing the matters of calculational conservatism and realism that Appendix I means, implicitly, that any facility that conforms to the numerical and other conditions thereof is acceptable without further question with respect to section 50.34a... The numerical guidelines are, in this sense, a conservative set of requirements and are indeed based upon conservative evaluations." [Supplementary Information, Part C, pp. 5, 6]

Comment This conclusion is in error, possibly because of a misreading of the Appendix I Statement of Considerations. The Commission's opinion referenced above does not say that the models are conservative, as suggested by the EPA interpretation. Rather, the Commission has stated that Appendix I sets forth conservative design objectives which were arrived at by conservative techniques (e.g., linear extrapolation of radiation effects to low levels) and that the degree of conservatism inherent in the selection of Appendix I design objectives negates the need for further conservatism in the form of licensing evaluations or more restrictive dose limits. This quoted paragraph is in direct contradiction to the proposed 40 CFR Part 190 since the paragraph states a formal conclusion by NRC, based on practicability considerations, that limits more restrictive than those imposed by Appendix I are not warranted for nuclear power reactors (e.g., site limits in addition to reactor limits).

As a general comment, the NRC and reactor licensees have instituted measurement programs to determine the sources, magnitudes, and species of radionuclides released in power plant effluents. On the basis of information received to date from these programs, we have made substantial revisions to our source term model for BWRs. The data obtained from recently initiated PWR measurement programs will be used to update the PWR model in coming months, in keeping with the NRC's commitment to keep the source term models consistent with operating data. It should be noted that data obtained to date have not shown the source term models to be "generally conservative," as indicated by the EPA [Supplementary Information, Part C, p. 10], but have shown in several cases that model revisions were needed to keep from underestimating radioactive releases. It should be remembered that the NRC's models are designed to predict radiological effects over the projected 30-year operating life of the plant, and that disparity between predicted average releases and short-term measurements may be indicative only of having chosen a sampling time or location that was not representative of "30 year average" conditions.

II. OTHER FACILITIES IN THE URANIUM FUEL CYCLE

A. Technical Data Base

The numerical dose and release quantity limits specified in the proposed regulation reportedly are based upon the information contained in the EPA Draft Environmental Impact Statement (DES) and the three volume report Environmental Analysis of the Uranium Fuel Cycle. Additional information was presented in the report "Supplementary Information" but this report was issued well after the limiting values were selected.

We have related some of the difficulties which AEC encountered in the Appendix I rulemaking due to an inadequate data base for LWR reactor several of which had been in operation for more than a decade. Even less applicable data are available for most other facilities in the uranium fuel cycle.

The AEC had planned that similar guidance for other fuel cycle facilities would be developed after completion of the rulemaking action to provide numerical guidance for LWR effluents. A Federal Register notice of intent for rulemaking to this effect was published by AEC in 1974. Recognizing that a sound technical data base is required for selecting such values, the AEC contracted ORNL in 1973 to initiate a comprehensive technical study of fuel cycle facilities, including uranium mills, UF_6 refineries, mixed oxide fuel fabrication facilities, and fuel reprocessing plants. In reports of these studies, ORNL provided evaluations of radiation source terms, evaluation of process equipment capabilities, estimated process equipment costs, and calculated potential doses to individuals and to populations in the region of a site. Basically, this is the type of information we found to be absolutely necessary in our Appendix I rulemaking. The ORNL studies were performed under the direction of AEC and continued under NRC. Four reports on these studies were issued by ORNL* in May 1975.

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ORNL-TM-4901 Nuclear Fuel Reprocessing
ORNL-TM-4902 Fabrication of LWR Fuel from Enriched UO_2
ORNL-TM-4903 Vol. 1 - Milling of Uranium Ores
Vol. 2 Preparation of Cost Estimates for Vol. 1
ORNL-TM-4904 Fabrication of LWR Fuels Containing Pu.

After reviewing the information in these reports and evaluating the nature of the data and other information the NRC staff has concluded that the technical data and information for all types of uranium fuel cycle facilities, except reactors, are inadequate to provide technical bases for selecting generic ALARA numerical guidelines at this time. We arrived at this conclusion for three principal reasons.

(1) Effluent data now available are adequate to provide reasonable assurance of compliance with RPGs but inadequate to demonstrate the feasibility of complying with generic ALARA numerical guideline values which are a small fraction of the RPGs, particularly for facilities with design features which have not been operated in commercial-scale plants of the design type being considered.

(2) An interim value for the monetary worth of incremental reductions in population doses ($1,000/person-rem) was selected for Appendix I cost-benefit evaluations but rulemaking proceedings on this issue may result in a change in this value; consequently, it would be untimely to apply the interim value to other than reactor facilities at this time.

(3) The NRC is considering a staff recommendation to issue its own technical status reports utilizing the ORNL effort, inter alia, rather than using the information for NRC ALARA rulemaking actions, as originally intended.

We caution that these ORNL reports provide theoretical, not empirical, analyses relative to the conclusion that implementation of the proposed standard is practicable and feasible. We do not agree the conclusion that these reports support a finding of practicability or feasibility of compliance with the proposed 40 CFR Part 190.

We also caution that ORNL-TM-4901 (Reprocessing) is currently being revised to reflect current licensing practices and evaluations. The revisions could be substantial, particularly with respect to equipment effectiveness for control of iodine releases and the associated cost-benefit analyses. Furthermore, the current baseline analyses for fuel reprocessing plants in the NRC Generic Environmental Statement for Mixed Oxide fuels show potential maximum annual thyroid doses of a few hundred mrem for typical FRP sites. These are far in excess of the 75 mrem annual limit in the proposed standard.

B. Fuel Reprocessing Plants

One commercial fuel reprocessing plant (FRP) has been operated in the United States. This FRP had a small capacity and most of the fuel processed had relatively low burnup. This plant is currently shutdown for extensive modification to increase processing capacity, to incorporate a new process (not yet selected) to solidify liquid wastes, to add equipment (not yet selected) to convert plutonium compounds to oxide forms and to modify other station features. Another FRP (Barnwell) is in the licensing process and construction is nearly completed. Design features of this new FRP differ substantially from those of the first FRP; consequently, data obtained from previous operation of the first FRP will not necessarily be applicable to the second. The Barnwell FRP will include advanced design features for which no commercial operating data are available. However, testimony presented during the licensing process for the second FRP indicates that potential release quantities of long lived material from this FRP and potential thyroid doses could exceed the proposed standard.

The practicability of installing krypton recovery equipment in the Barnwell FRP was evaluated by NRC staff in the course of licensing action for that facility. We estimated that the Kr-85 could cause an annual dose of 17 man-rem among the 657,000 persons living within 50 miles of the plant. We also estimated that C-14 could cause an annual dose of 59 man-rem to the same population. The cost of krypton recovery equipment estimated by ORNL, by Allied General Nuclear Services, and by Allied Chemical Corporation ranged from at least $5 million to about $40 million. An annual cost of $2.0 million was estimated for a $5.6 million capital cost system, which includes minor additions to be capable of recovering C-14. If the system with the lowest estimated cost were to capture 100% of the Kr-85 and C-14, the calculated annual dose to the population within 50 miles might be reduced by 76 man-rem at an annual cost of $2.0 million, or about $27,000 per man-rem reduction. We do not now consider this practicable from a cost-benefit consideration.

Practically, it is not possible to recover or to retain 100% of either the Kr-85 or the C-14 and it is conceivable that the $40 million capital cost estimate is more accurate than the $5.6 million cost estimate; thus the cost-benefit value could be even less acceptable. A larger value for the reduction of the population annual dose (commitment) can be calculated by summing the infinitesimal annual doses to the entire population of the Earth over several decades, as advocated by EPA. We do not believe that such a value is significant at this time, considering the number of FRPs. if viewed with <u>any</u> perspective such as comparisons to variations in natural background radiation with location, or other similar source comparisons.

We recognize that the cumulative inventory of Kr-85 (and other long-lived radionuclides) in the atmosphere could attain undesirably high levels by the year 2000 or later owing to the contributions from all FRPs on Earth if Kr-85 releases are not restricted by that time. We are confident that such restrictions will be provided by FRPs in the U.S. long before this <u>potential</u> problem becomes a <u>real</u> problem. Our principal differences with EPA on this issue are (1) the specific time at which it is proposed to require the restictions on releases, (2) the unilateral nature of the action, (3) the administrative problems created by stating the limits in terms of electrical energy produced, and (4) the specific nature of the proposed standard (e.g., facility specific rather than a generally applicable environmental standard).

Aside from the "practicability" issue, the proposed 40 CFR Part 190 would require application of krypton recovery equiptment in all commercial FRPs by 1983 and no effective variance provision is provided for FRPs which exceed the standard [Supplementary Information, Part A, p. 11]. A substantial research and development effort is required before krypton recovery equipment is available for commercial FRPs. If 10 years are required for the R&D effort, as estimated by ORNL and others, compliance in 1983 would not be possible. Presumably, the date for compliance could be changed if this is the case. The lack of an effective variance provision for FRPs is a more difficult matter. Without a variance, exceeding the Kr-85 limits presumably would be cause for shutdown. In order to avoid costly shutdown in the event the Kr recovery equipment is inoperative, it is likely that redundant equipment would need to be provided. This redundant equipment would further increase the cost of equipment (recall that one cost estimate for a system which included redundant equipment was $40 million) and would decrease the cost-effectiveness of krypton removal.

In addition to these processing problems, additional problems must be identified and resolved, including safety issues concerning the operation of the equipment, and the handling, transportation, and long term storage or ultimate disposal of the collected Kr and other long-lived material. The costs or impact of these items also must be included in a realistic cost-benefit analysis.

In this regard, the National Council on Radiation Protection and Measurements, on July 1, 1975, issued NCRP Report No. 44 "KRYPTON-85 IN THE ATMOSPHERE - Accumulation, Biological Significance, and Control Technology". In the Summary, NCRP makes the following observation.

> "The dose from 85-Kr for the next several years will be of such a low order as to preclude the need for installation of recovery systems. However, as such systems become available for full-scale application, their installation in fuel reprocessing plants should be considered in relation to the costs of such installations and the benefits, if any, that would result."

In the Discussion, NCRP recommends international collaboration on this issue rather than the unilateral action required by the proposed standard.

> "In this report the subject has been addressed from the point of view of the United States atomic energy program. It is estimated that by the year 2000, the United States installed nuclear electric power capacity will be about 1000 GW compared to nearly 5000 GW for the world. Any policy adopted by the United Sates would thus deal with about 20 percent of the 85-Kr generated in the year 2000. This is clearly a general

question that requires careful international collaboration and the NCRP urges that the International Atomic Energy Agency and the International Commission on Radiological Protection give prompt attention to the need for developing policies that will be acceptable on an international scale."

<u>This NCRP recommendation is in complete accord with our previous recommendations to EPA [see attached comments dated September 15, 1975].</u>

C. <u>Uranium Mills</u>

Uranium mills in the United States generally are located in arid regions with relatively sparse populations. Tailings piles (i.e., solid waste from the milling process released as a slurry and generally retained by earthen dam systems) are recognized as an important source of airborne radioactive material offsite. In most instances, the nearest inhabitated area is well beyond the perimeter of the tailings and, owing to the arid nature of the region, locally produced vegetables are not commonly found. Tailings piles are subject to erosion by wind as the solid material dries. Airborne radioactive material from these tailings is extremely variable and representative samples obtained from monitoring programs are difficult to evaluate with respect to estimating potential dose equivalents on a yearly average basis for the lifetime of the facility. Furthermore, sufficient data on airborne radioactive material from tailings to estimate potential doses from all exposure pathways do not exist. The source term characterization presented in the ORNL studies* and cited by EPA [Supplementary Information, Part H, p. 1] are based primarily, on <u>calculations</u> which require the selection of parametric values, for which data are not available, and represent judgement which has not been verified by measurements. The estimated source terms and

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*ORNL-TM-4903, Volumes 1 and 2.

calculated potential doses do not contribute the needed data base required to select the values in the proposed standard or to judge the feasibility of complying with the proposed standard.

EPA suggests that readily available techniques such as stabilizing the tailings with "chemical binders" or covering the tailings with soil would eliminate completely the erosion by wind and assure compliance with the proposed standard. [Supplementary Information, Part A, p. 8]. NRC staff is not aware of any method which has been demonstrated to provide stabilization of active tailings piles sufficient to assure compliance with the proposed standard. Further, we are not aware of any cost effectiveness evaluation provided by EPA for stabilization of mill tailings.

We are aware of an ongoing research project being jointly sponsored by ERDA and EPA to study mill tailings. This project, which is projected to be completed in 1977 will have cost about $2.5 million and will provide a substantial amount of information concerning:

1) Gamma dose rates from windblown tailings;
2) Soil sample analysis to determine content of Ra-226 and other radionuclides;
3) Background concentrations of Ra-226;
4) Erosion of tailings by rainfall and streams;
5) Leaching of activity from tailings to aquifers;
6) Migration of activity from tailings into subsurface soils;
7) Air concentrations of radon and daughters
   - long term and short term

- correlation with meteorologic conditions
- "exhalation" rates for radon from tailings piles;

8) Population exposure estimates;
9) Analyses of tailings components;
10) Contamination levels of land and buildings near site;
11) Alternative milling processes to remove more radioactive material from tailings before discharge;
12) Determine factors which affect "exhalation" rate from tailings, e.g., temperature, barometric pressure, moisture, compaction, thickness and characteristics of cover materials, etc.;
13) Effectiveness of controls of sealants above and/or below the tailings; and
14) Effectiveness of vegetation covering over the tailings piles.

It is precisely this kind of information which is now lacking and which we believe is necessary to provide the basis for rulemaking or other generic regulatory actions on mills. For reasons such as those described above, the NRC is currently considering a staff recommendation to initiate a generic Environmental Impact Statement and associated studies for uranium mills.

D. Uranium Enrichment Facilities

NRC has never received an application for a commercial enrichment plant license so our licensing experience in this area is nil. We note that EPA has not provided a cost-benefit study for enrichment plant effluent controls. Consequently, we do not understand why these facilities have been included in the proposed 40 CFR Part 190. Since NRC has not licensed uranium enrichment facilities, we recommend that ERDA speak to the feasibility and cost-effectiveness of these facilities complying with the proposed standard.

E. UF_6 Conversion Facilities and Enriched Uranium Fuel Fabrication Plants

From our studies to date, we believe that it is likely that conversion facilities and enriched uranium fuel fabrication plants practicably can comply with the proposed standard.

F. Transportation of Radioactive Material

For sites which require substantial numbers of shipments of radioactive material, the proposed standard would require the apportionment of dose limits, not only among the facilities on the site and nearby facilities, but also adjusted to accommodate the contribution from transportation. Additional radwaste equipment could be required to provide the additional dose reduction from the facilities to accommodate the dose contribution from transportation. This could require radwaste equipment for control of radioactive material in effluents beyond that considered to be "justifiable" by EPA when considering potential doses from effluents alone.

We defer to the Department of Transportation, which is responsible for regulation of the transportation of radioactive material by trucks, to speak to the feasibility of compliance with the proposed standard and the practicability of compliance in terms of cost-effectiveness beyond the site boundary. We note that EPA has not provided a cost-benefit justification for inclusion of the transportation source term in the proposed standard.

III. EPA TECHNICAL REPORTS

We have reviewed the Draft Environmental Statement; the Environmental Analysis of the Uranium Fuel Cycle, Part I - Fuel Supply, Part II - Nuclear Power Reactors, and Part III - Fuel Reprocessing, EPA - 520/9-73-003; the report Environmental Dose Commitment: An Application to the Nuclear Power Industry, EPA - 520/4-73-002; and the Policy Statement: Relationship Between Dose and Effect, ORP. In order to make a complete evaluation of these reports, it would be necessary to essentially duplicate the studies independently and then to compare differences; we have not done this. However, our review disclosed a substantial number of items where we and EPA differ in technical evaluations, economic considerations, judgments, and conclusions. It is not worthwhile discussing the details of the numerous technical differences which we have with these reports at this time, but there are some important issues which we will identify.

A. Source Terms

Essentially all of the postulated health effects (1020 of 1030) which EPA believes will be averted by promulgation of the proposed 40 CFR Part 190 would be due to retention of long-lived material [DES, p. 82, Table 10]. Fuel reprocessing plants are the dominant consideration in this regard. Among the assumptions used in estimating the number of averted health effects is the assumption that the postulated effluent characteristics of the typical FRP analysed by EPA will be representative of the 50 FRPs to be operated over the next 50 years [Supplementary Information, Part F, pp. 24].

While it is recognized that NRC has an effective ongoing generic effort to assure that releases of radioactive material in effluents of LWR stations are "as low as reasonably achievable" as part of the licensing process, the EPA analysis does not recognize that the same licensing finding is required for FRPs on a case-by-case basis. With respect to krypton recovery, NRC staff has taken the position that FRP licensees should provide adequate space to permit installation of krypton removal equipment when it becomes available and the FRP scheduled for operation in 1985 will include krypton recovery equipment (the EXXON facility). Thus, even without the proposed standard, of the three commercial FRPs which will operate in the U.S. by 1985, one will control krypton release and the other two will be able to accommodate the processing equipment when it becomes available. Assuming that development of technology for krypton recovery equipment continues to advance favorably, it is reasonable to assume that effective krypton control will be provided by FRPs in the U.S. within a decade. Similar changes in the design features of the FRPs to provide further control of the release of other long lived material also can be anticipated. This means that 1020 of the 1030 averted health effects associated with the proposed 40 CFR Part 190 will in fact be averted even if 40 CFR Part 190 is withdrawn today. Thus, the principal benefit claimed for the proposed standard is not real.

B. Health Effects

We have reviewed the EPA Policy Statement, dated March 3, 1975, concerning the adoption of the theoretical linear, nonthreshold, dose rate independent relationship of dose and biological effects extrapolated to zero dose. We do not agree with the adoption of this theory (and we emphasize that it is a theory rather than an established fact) without reservation and proceeding to treat the resulting calculated risk values as though they were actual risks. The data available today do not rule out a zero risk from low doses delivered at low dose rates. Thus we believe that when integral population doses are calculated from low doses at very low dose rates and related to calculated health effects, a factually correct statement would be that the number of health effects is likely to be within the range from zero to N, where N is the value calculated using the linear theory. Since cost-effectiveness is judged by EPA in considering the cost of averting potential health effects, it is important to realize that if the health effects are indeed zero, any cost realized to reduce the value is not justified from a health viewpoint.

The importance of the issue is apparent when considering the cost-effectiveness of Kr-85 capture. The numerical integration of the very low level doses delivered at very low dose rates for several decades to the entire population of the Earth is necessary to justify Kr-85 capture on a cost-effective basis. This rationale completely ignores that (1) the number of health effects might be zero; (2) if not zero, the number is statistically insignificant when any perspective is provided; and (3) the contribution to the world-wide Kr-85 inventory from sources outside the U.S. will exceed substantially those originating within the U.S. The National Academy of Science, on p. 17 of the 1972 BEIR Report, states "Tritium and krypton-85 should be assessed on a basis of world-wide production because of their distribution patterns" (Emphasis added). In our previous written comments to EPA, we pointed out that the control of long lived radioactive material which could be dispersed world-wide is an international problem and unilateral actions on the part of the United States would have only a modest effect on reducing the world-wide dose commitments. We continue to believe that international discussions on this matter would be more appropriate than promulgation of a National standard at this time.

Recognizing that EPA has applied the linear theory to all non-zero doses, we do not understand why the 100-year time interval was arbitrarily selected for integrating doses used to calculate health effects. A time interval of thousands or millions of years would be equally rational and equally arbitrary.

An additional area of concern is that the selection of thyroid dose limits based on the "biological equivalent" of whole-body dose has not been demonstrated [DES-pp. 65-66]. Using the risk values selected by EPA, it can be shown that the thyroid dose would have to be several times higher than the factor of three times the whole body dose to be "biologically equivalent."

C. Economic Considerations

The EPA reports do not present the detailed cost values needed to independently verify important elements of the costs. Further, solid waste handling systems were not included in EPA radwaste costs.

EPA utilizes a discount rate procedure for radwaste system costs but does not employ a similar procedure to discount potential health effects in the future. This costing procedure improves the apparent cost-effectiveness. Perhaps a discounting procedure is applicable to both costs and postulated health effects. It is clearly incorrect to discount one side of the cost-benefit equation and not the other. In the absence of a method for translating health effects into economic benefits, comparisons should be made on an undiscounted basis. Certainly, it is a subject worthy of discussion among economists and radiation protection experts.

EPA does not explain how the dose limits for individuals were justified by "...weighing cost-effectiveness and cost of control relative to the total capital cost..." [DES, p. 24]. If the values selected for the annual dose limits for individuals are justified only on the basis of the cost of controls relative to the capital cost of the facility, the procedure would not preclude arbitrary decisions to require controls which are not cost-effective.

The DES for the proposed EPA standard does not provide a detailed description of the radwaste systems which would be required to meet the proposed standard or provide the reasoning process by which the values in the proposed standard were selected. However, the systems required can be identified from the data included in Figure 12 of the DES. When this information is used in conjunction with the cost-effectiveness data of Figure 4 of the DES it can be seen that use of some of these "required" systems would result in spending substantially more than the $500,000 per potential health effect averted, which the DES indicates is the least cost-effective of the systems which should be required.

The radwaste systems identified by this analysis are described in the three volume set on the Environmental Analysis of the Uranium Fuel Cycle issued by EPA in 1973. The costs per averted potential health effect can be derived from these data and are shown in Table A, below. The values range from a low of $0.79 million to a high of $29 million per averted potential health effect. It may be that EPA did not mean for all of these systems to be required, the presence or absence of a given system in Table A being determined by the absence or presence of the letter "P" following the radwaste system description in Figure 12 of the DES. But it does indicate the need for a far more detailed examination and description of the reasoning process by which the values in the proposed standard were derived. There are indications that at least some of the dose models used in the analysis may overestimate the doses and some of the costs may be underestimated. If alternative values were used the costs per averted potential health effect could be substantially higher.

Table A

Required Radwaste Systems for Which the Costs per Averted Potential Health Effect Exceed $500,000

Radwaste System	$ Millions Health Effect	Reference Vol.	 Table #	 Page
HEPR drying system (Mill)	1.4	I	2-11	52
Bag (crushing) filter (Mill)	29(a)	I	2-11	52
Seepage return (Mill)	6.7	I	2-12	53
2nd bag filter (Conv. WS)	0.79	I	3-10	93
2nd bag filter (Conv. HF)	5.3	I	3-10	93
Settling tanks (Fuel Fab)	1.2	I	5-12	135
Iodine Case (BGIE-2-BWR)	19.	II	57	153
Liquid Case BWR-3	7.8	II	61	157
Iodine Case PGIE-3-PWR	3.8(b)	II	59	155

(a) Value from Figure 4 is about 3.

(b) Value from Figure 4 is about 10.

IV. CURRENT NRC EFFORTS

Current NRC regulations require that exposures of persons to radiation be maintained at as low as reasonably achievable levels below existing Federal Radiation Council guidance. In this regard, Appendix I of 10 CFR Part 50 provides numerical guidelines for light water reactor effluents. For other facilities, for which no generic numerical guidelines are currently available, ALARA levels are determined on a case-by-case licensing basis. When an adequate technical data base exists for these other facilities, generic numerical guidelines likely will be proposed by NRC. Having recognized the inadequacy of the current data base, technical programs have been initiated to obtain the required additional data. We are optimistic that this information will be available within the next several years.

NRC and EPA staffs have been cooperating in programs to obtain data which will permit better predictions of dispersion and deposition of radioactive material in the environs of nuclear facilities. Data collected by this program to date are the best available, but much more extensive data and analyses still are needed if the current analytical models are to be improved. We believe that this cooperative effort not only should continue, but should be expanded to provide the sound data base which both agencies (and others) recognize as being required.

NRC has participated in joint meetings with General Electric and EPA to discuss technical issues concerning N-16 "shine" from BWR turbines. We believe that these meetings can lead to the satisfactory resolution of this problem area and this would be more desirable than the present case where N-16 shine has been included in the proposed standard without a cost-benefit determination.

V. IMPACT OF 40 CFR PART 190 ON NRC ACTIVITIES

We have previously cited several administrative and technical problems which would pose a substantial burden on the NRC if 40 CFR Part 190 is promulgated [see letter to Russell E. Train from Lee V. Gossick dated September 15, 1975 appended to this testimony]. EPA acknowledges that a substantial number of revisions would be required in NRC regulations, regulatory guides, and technical specifications [Supplementary Information, Part A, pp. 13-14], but underestimates the effort required to make these revisions. While the administrative burden would be substantial indeed, perhaps a greater burden would be the technical effort required by our Office of Inspection and Enforcement which would be responsible for verifying compliance by licensees of all uranium fuel cycle facilities.

A. Environmental Measurements

EPA has indicated that environmental measurements should be made to confirm noncompliance with its standard when calculational values indicate that such confirmation is necessary [Supplementary Information, Part A, p. 5]. However, EPA has not addressed any of the difficulties or uncertainties that can be encountered in applying this approach or made any estimate of the effort and cost that such a program would involve. Neither has any data been presented to support the conclusion that such an approach can, in fact, be applied successfully in actual practice.

Environmental monitoring as a means of measuring dose and demonstrating compliance with an exposure limit (RPG) has some of the same limitations and uncertainties as do calculational models based on effluent data. Therefore, simply making an environmental measurement does not mean that we have accurately determined dose and demonstrated compliance. Estimations of radiation exposures based on environmental data are subject to substantial error. One of the greatest uncertainties is how closely the measured environmental level or concentration represents the actual exposure.

These uncertainties in dose estimates based on environmental measurements are a result of the following considerations.

(1) Low concentrations or dose rates are very difficult to measure and even more difficult to distinguish from already existing levels or background levels. This results in a net measured value which has a large uncertainty associated with it.

(2) Sample distributions resulting from variable or intermittent releases from stationary sources are not well understood and therefore the relationship between sample measurements and the data population from which these samples have been collected is not well defined. Extrapolation of data from individual samples to the sample population can therefore potentially lead to considerable error.

(3) The habits, intakes, and ages of individuals vary considerably and are subject to constant change. The variability and changeability of these parameters can introduce considerable uncertainty into dose estimates.

Because of these large uncertainties, data from present "state-of-the-art" monitoring programs can provide only rough estimates of the potential radiation exposure to an individual. Since the range of these exposures are still well below the present RPGs, these programs have been deemed to be adequate for the purposes for which the data are used. However, if environmental monitoring programs were required to provide data to accurately determine compliance with RPGs 1/20 of the present values, then the present "state-of-the-art" monitoring programs would be totally inadequate. Extensive and costly monitoring programs would have to be implemented to assure compliance with the proposed EPA standard. An environmental "compliance monitoring program" for demonstration of compliance with the EPA standard would have to include the following:

(1) frequent measurements taken over long periods of time would be required to assure that the data closely represents the exposure pathway measured;

(2) a large number of sampling locations would have to be utilized to assure that the variability of dose rate or concentration with location has been adequately considered;

(3) the sample distribution would have to be established in order to assure that the samples collected can be interpreted with respect to the population which they are meant to represent;

(4) extremely reproducible measurement techniques would have to be employed in order to be able to distinguish between dose-rates resulting from releases from a facility and those already existing or background levels; and

(5) to be able to distinguish this incremental dose above background it would be necessary to continually maintain an extensive program for measuring background dose-rates and concentrations so that this data base will be available should "compliance monitoring" be required.

EPA refers to a number of special field studies which it has conducted at various operational uranium fuel cycle facilities. It is informative to recognize that even these costly studies, in most instances, would not have provided an adequate data base for determining compliance with the proposed EPA standard based on environmental monitoring data. The time periods over which some of the environmental measurements were made were relatively short and the frequency of sampling was very limited with collections in some cases being limited to a single sample.

B. FRC Guidance

Since EPA has stated that the proposed 40 CFR Part 190 as a revision of the current RPG values for the nuclear power industry [Supplementary Information, Part A, p. 3], it is instructive to consider the existing FRC guidance for implementing RPGs because it includes guidance for environmental surveillance and control. The FRC, in its Report No. 2 of September 1961 "Background Material for the Development of Radiation Protection Standards," presented guidance which included a graded scale of action to be taken to assure compliance with the current RPGs.

The following information is quoted from the FRC Report No. 2.

> "Control of Environmental Radioactivity
>
> 1.16 The objective of the control of population exposure from radionuclides occurring in the environment is to assure that appropriate RPG's are not exceeded. This control is accomplished in general either by restrictions on the entry of radioactive materials into the environment or through measures designed to limit the intake of such materials by members of the population. The most direct means of evaluating the effectiveness of control measures is the determination of the amount of radioactive material in the bodies of the members of exposed population groups. Although the determination of such body burdens may at times be indicated in routine practice potential exposures will generally be assessed on the basis of either one or a combination of two general approaches: (1) calculations based upon known amounts of radioactive material released to the environment, and assumptions as to the fraction of this material reaching exposed populations groups, or (2) environmental measurements of the amount of radioactive material in various environmental media.

1.17 Both of these general approaches involve the calculation or determination of actual or potential concentrations of radioactive material in air, water, or food. As stated above, controls should be based upon an evaluation exposure with respect to the RPG. For this purpose, the average total daily intake of radioactive materials by exposed population groups, averaged over periods of the order of a year, constitutes an appropriate criterion.

1.18 There is for any radioactive material a daily intake which is calculated to result, under specified conditions, in whole body or organ doses equal to a Radiation Protection Guide. The resulting value represents either the continuous or the average daily intake of radioactive material might fluctuate very widely around the average and still result in an annual dose which would not exceed the associated RPG.

1.19 The control of the intake of radioactive materials from the environment can involve many different actions. The character and import of these actions vary widely from those which entail little interference with usual activities, such as monitoring and surveillance, to those which involve a major disruption, such as condemnation of food supplies. Some control actions would require prolonged lead times before becoming effective, e.g., major changes in water supplies. For these reasons, control programs developed by the agencies should be based upon appropriate actions taken at different levels of intake. In order to provide guidance to the agencies in developing appropriate programs, this report describes a graded approach for the radionuclides considered, involving three ranges of transient rates of daily intake applicable to different degrees or kinds of action.

1.20 The objective of the graded scale of actions is to limit intake of radioactive materials so that specified RPG's will not be exceeded. Daily intakes varying within the total extent of all three ranges of intake might result in annual doses not exceeding a single RPG. However, in instances in which the daily intake is fluctuating above the average which would meet the RPG, it may not be possible to be assured that this will be the case. The actions outlined below would be appropriate, not only when intakes are fluctuating so as not to exceed a given RPG, but also in those situations in which valid reasons exist for the responsible agency to permit the possibility of doses which would exceed the RPG.

1.21 A suggested graded system of actions is outlined below. For each of the ranges of transient rates of daily intake, specific values for which are given in the sections devoted to the specific radionuclides, the general type of action appropriate for the range is outlined.

RANGE I*

Intakes falling into this range would not under normal conditions be expected to result in any appreciable number of individuals in the population reaching a large fraction of the RPG. Therefore, if calculations based upon a knowledge of the sources of release of radioactive materials to the environment indicate that intakes of the population are in this range, the only action required is surveillance adequate to provide reasonable confirmation of calculations.

RANGE II*

Intakes falling into this range would be expected to result in average exposures to population groups not exceeding the RPG. Therefore such intakes call for active surveillance and routine control.

Surveillance

Surveillance must be adequate to provide reasonable assurance that efforts being made to limit the release of radioactive materials to the environment are effective. Surveillance must be adequate to provide estimates of the probable variation in average daily intake in time and location. Detection of sharply rising trends is very important. In some cases, because of the complexities of the environment, surveillance data may have to be sufficiently reliable to be used as a rough check on whether radioactive materials in the environment are behaving as expected. Not only the radioactive material in question, but also the environment must be studied. Appropriate efforts might be made to obtain measurements in man as well as to study physical, chemical, and metabolic factors affecting intake. Appropriate consideration should be given to other independent sources of exposure to the body (the same organs or different ones) to avoid exceeding RPG's.

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*Further FRC guidance indicates that Ranges I, II, and III correspond to 0 to 10%, 10% to 100%, and >100% of the RPG values, respectively, for suitable samples of the exposed population group.

Control

Routine control of useful applications of radiation and atomic energy should be such that expected average exposures of suitable samples of an exposed population group will not exceed the upper value of Range II. The sample should be taken with due regard for the most sensitive population elements. Control actions for intakes in Range II would give primary emphasis to three things: (1) assuring by actions primarily directed at any trend sharply upward that average levels do not rise above Range II, (2) assuring by actions primarily directed either at specific causes of the environmental exposure levels encountered or at the environment that a limit is placed on any tendencies of specific population segments to rise above the RPG, and (3) reducing the levels of exposure to segments of the population furthest above the average or tending to exceed Range II.

RANGE III*

Intakes within this range would be presumed to result in exposures exceeding the RPG if continued for a sufficient period of time. However, transient rates of intake within this range could occur without the population group exceeding the RPG if the circumstances were such that the annual average intake fell within Range II or lower. Therefore, any intake within this range must be evaluated from the point of view of the RPG and if necessary, appropriate positive control measures instituted.

Surveillance

The surveillance described for intakes in Range II should be adequate to define clearly with a minimum of delay the extent of the exposure (level of intake, size of population group) within Range III. Surveillance would need to provide adequate data to give prompt and reliable information concerning the effectiveness of control actions.

Control

Control actions would be designed to reduce the levels to Range II or lower and to provide stability at lower levels. These actions can be directed toward further restriction of the entry of radioactive materials after entry into the environment in order to limit by humans. Sharply rising trend in Range III would suggest strong and prompt action." (Emphasis added)

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[*] See footnote on previous page.

The FRC guidance is practicable at current RPG levels but becomes impracticable (if not impossible) at the lower levels of the proposed standard because at the lower levels the environmental monitoring and radiochemical analyses will require use of techniques and procedures that are currently associated with research or special laboratory studies. Further, since the lower RPG values proposed by EPA are very near the operational levels which we anticipate for the uranium fuel cycle facilities, a substantial number of facilities can be anticipated to be in all three of the FRC "ranges" described above and will require extensive additional surveillance and controls.

C. NRC Surveillance

In the existing NRC regulatory program for effluent controls there are two levels which are of concern to our Office of Inspection and Enforcement. The first is the 10 CFR Part 20 limit which corresponds to FRC guidance, and the second is the design objective guidance which corresponds to essentially one percent of the 10 CFR Part 20 limit for each LWR on a site. The level at which a licensee must initiate some kind of action occurs at two times the ALARA design objective guidelines. At this level, we can rely heavily on modeling, even though imprecise, because for a single LWR we are still a factor of fifty below the FRC limit. Consequently, environmental monitoring is not used as the basis for determining the potential dose to individuals--but rather as a backup to the effluent monitoring program, as a means of public assurance, and as an indicator of the general applicability of the models. Reliance on modeling using effluent release data has been preferred for practical rather than philosophical reasons. At the present state-of-the-art it would be impossible for routine monitoring programs to determine actual doses to real individuals.

In addition, we have always believed strongly that enforcement should be immediate and not retrospective. Consequently, effluent release limits back-calculated from dose models are a more reasonable means of regulating the operation of a nuclear reactor or other facility than environmental samples--the results of which generally require laboratory analyses which involve a waiting period of several weeks. In that respect, the Commission has indicated in the Statement of Considerations for Appendix I that measurements of Appendix I levels in the environment would not be required and that compliance with Appendix I would be based on dose modeling calculations. Now, however, the proposed standard would eliminate the large gap between design objective values and the applicable radiation limit. If NRC or the licensee is required to verify compliance with the proposed standard it would be reasonable that such verification procedures would not wait until it is assumed that the standard has been exceeded but, rather, verification would begin at some level below the 40 CFR Part 190 limit. This, of course, would be contrary to the philosophy that the Commission has previously stated and would require additional monitoring effort. If we follow the FRC guidance for the ranges discussed above for the RPG values proposed by EPA, NRC or the licensee will be required to initiate verification procedures at 10% of the 40 CFR Part 190 values which would correspond to 50% of the design objective quantities of Appendix I for a single reactor on a site.

At the present time, we are not certain as to the frequency with which environmental studies would have to be implemented to determine compliance with the proposed EPA standard or if such studies could demonstrate non-compliance. With the general philosophy expressed in the Commission's opinion on Appendix I to use more realistic assumptions in determining environmental impact, it is reasonable to assume that a substantial number of LWRs, and probably most of the other facilities in fuel cycle, during their lifetime, will require additional studies of some aspect of their impact on the environment. These would be useful in better describing the uncertainties mentioned above.

It should also be recognized at this point that, as stated above, determining doses to individuals at these low levels is extremely difficult and is in general beyond the capabilities of the NRC licensees and beyond the scope of the "field studies" performed by EPA to date. Sampling and analytical procedures for many of the pathways must still be developed. At the levels which EPA is proposing as limits for the uranium fuel cycle facilities, monitoring becomes very difficult and expensive. For example, TLDs are currently used to measure exposure rates near the site boundaries of reactors. Relative to other instruments, such as pressurized ionization chambers, TLDs are very inexpensive. However, TLDs are not adequate to measure exposure rates at the low levels of our ALARA effluent controls or the proposed standard. If such measurements must be made, pressurized ionization chambers will be required. We estimate that such systems would cost more than $100,000 per site plus operating expenses. For this reason, and also because in many instances verification of compliance would entail regional aspects (that is, the summation of doses from two or more facilities), the responsibility for these programs is likely to fall on the NRC rather than on our licensees. This concept of divided responsibility for environmental monitoring is distasteful since it runs counter to the practice of placing responsibility for the operation of a facility on the licensee. If NRC must conduct verification programs because of their complexity or expense, or because of a perceived need for an official verification in the granting of variances, then there is a considerable added administrative, technical, and economic burden to NRC.

At the present time, we have a limited arrangement with the Health Services Laboratory in Idaho Falls, Idaho whereby periodic intercomparisons are made with licensees to confirm specific measurements or to determine the analytical capability of a licensee. This program could form a basis for an extended program as outlined above. A more efficient approach would be to establish an NRC laboratory. It is difficult to make estimates of the man-years of effort required for individual studies. However, as a first approximation, we believe that a laboratory with the capability and size of the ERDA Health and Safety Laboratory, New York City, would be required. Because of the peculiarities of a regulatory agency in this situation we believe this laboratory (1) must have national recognition, (2) must have experience with the type of activities NRC regulates, (3) must not perform these services for the nuclear industry, (4) must have proven expertise in a wide range of technical areas and (5) must have a philosophy and mode of operation that will be responsive to the problems which will be presented.

In order to provide some perspective as to the costs of operating such a laboratory, the Health and Safety Laboratory (HASL) currently employes 106 people, (60 professionals) and has an FY 76 total budget of $4,500,000 plus $200,000 for equipment. The additional need for technical and administrative management of the laboratory and the program it would conduct would probably require about 10 more persons. Such a laboratory would be required to do instrumentation, radiochemistry and sampling procedure development plus respond as needed to perform verification analyses. We estimate that the capital cost of the equipment and auxiliary features of a laboratory like HASL to be about $2 million. A building of about 60,000 square feet also would be required.

VI. EXAMINING THE NEED FOR CHANGING RADIATION PROTECTION GUIDES

EPA on Page 13 of their DES, cites the National Academy of Sciences (BEIR Report) as presenting an admonition to lower the current radiation protection guidelines [DES, p. 13]. The full text of the paragraph, from page 2 of the BEIR Report follows.

> "There is reason to expect that over the next few decades, the dose commitments for all man-made sources of radiation except medical should not exceed more than a few millirems average annual dose to the entire U.S. population. The present guides of 170 mrem/yr grew out of an effort to balance societal needs against genetic risks. It appears that these needs can be met with far lower average exposures and lower genetic and somatic risk than permitted by the current Radiation Protection Guide. To this extent, the current guide is unnecessarily high."

We have underlined sections of the paragraph which were omitted in the EPA paraphrase of the paragraph. The omissions are important. We believe that NAS was not suggesting a need to change the RPGs generally, as stated by EPA. We believe that NAS was identifying a need to augment the current RPGs with population exposure guidelines (not standards). What NAS finds to be unnecessarily high is the population dose that would be permitted by the current limits of 500 mrem/yr for an individual and 170 mrem/yr for critical population groups if it were to be applied to every individual in the population. We will show how our interpretation is supported by the complete text in the BEIR Report.

Preceding the paragraph quoted above, the BEIR Report states:

> "Given the estimates for genetic and somatic risk, the question arises as to how this information can be used as a basis for radiation protection guidance. Logically the guidance or standards should be related to risk. Whether we regard a risk as acceptable or not depends on how avoidable it is, and, to the extent not avoidable, how it compares with the risks of alternative options and those normally accepted by society."

We have underlined what we believe is an important observation -- that in order to judge whether a risk is acceptable or not requires consideration of those risks which are normally accepted by society. We are not aware of any consideration given to this important factor in the studies leading to the proposed standard.

In the paragraphs which follow the one cited by EPA, further guidance is provided. Those paragraphs which are applicable to nuclear facilities are presented below.

> "It is not within the scope of this Committee to propose numerical limits of radiation exposure. It is apparent that sound decisions require technical, economic and sociological considerations of a complex nature. However, we can

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state some general priniciples, many of which are well-recognized and in use, and some of which may represent a departure from present practice.

a) No exposure to ionizing radiation should be permitted without the expectation of a commensurate benefit.

b) The public must be protected from radiation but not to the extent that the degree of protection provided results in the substitution of a worse hazard for the radiation avoided. Additionally there should not be attempted the reduction of small risks even further at the cost of large sums of money that spent otherwise, would clearly produce greater benefit.

c) There should be an upper limit of man-made non-medical exposure for individuals in the general population such that the risk of serious injury from somatic effects in such individuals is very small relative to risks that are normally accepted. Exceptions to this limit in specific cases should be allowable only if it can be demonstrated that meeting it would cause individuals to be exposed to other risks greater than those from the radiation avoided.

d) There should be an upper limit of man-made non-medical exposure for the general population. The average exposure permitted for the population should be considerably lower than the upper limit permitted for individuals.

f) Guidance for the nuclear power industry should be established on the basis of cost-benefit analysis, particularly taking into account the total biological and environmental risks of the various options available and the cost-effectiveness of reducing these risks. The quantifying of the "as low as practicable" concept and consideration of the net effect on the welfare of society should be encouraged."

"i) In regard to possible effects of radiation on the environment, it is felt that if the guidelines and the standards are accepted as adequate for man then it is highly unlikely that populations of other living organisms would be perceptibly harmed. Nevertheless, ecological studies should be improved and strengthened and programs put in force to answer the following questions about release of radioactivity to the environment: (1) how much, where, and what type of radioactivity is released; (2) how are thse materials moved through the environment; (3) where are they concentrated in natural systems; (4) how long might it take for them to move through these systems to a position of contact with man; (5) what is their effect on the environment itself; (6) how can this information be used as an early warning system to prevent potential problems from developing?

j) Every effort should be made to assure accurate estimates and predictions of radiation equivalent dosages from all existing and planned sources. This requires use of present knowledge on transport in the environment, on metabolism, and on relative biological efficiencies of radiation as well as further research on many aspects."

We strongly recommend these NAS principles and suggestions to EPA for consideration in deciding if, when, and in what form to issue 40 CFR Part 190. We believe that EPA has gone beyond these suggestions with the proposed standard and, in doing so, may be in contradiction to the recommendation in item (b) by attempting to reduce small risks even further at the cost of large sums of money that spent otherwise clearly would produce greater societal benefit.

Item (c) suggests that the upper limit of exposure for individuals in the general population should be such that the risk of serious injury from somatic effects in such individuals is very small relative to risks that are normally accepted. It is our understanding that this was a principal consideration in selecting the current RPGs and similar guidelines recommended by the National Council on Radiation Protection and Measurements (NCRP) and the International Commission on Radiological Protection (ICRP). We are unable to determine how EPA selected the values for annual dose limits for individuals in the proposed standard. We do not find a rationale in the EPA reports which indicates that the somatic risks at current RPG values are unacceptably

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high or that EPA's proposed reduction in annual dose limits for individuals is based on a finding of cost effectiveness. In fact, we cannot relate the annual dose limits for individuals proposed in the standard to any technical base developed in the EPA reports.

Item (d) speaks to the need for an exposure limit for the general population and suggests that the average exposure permitted for the population should be considerably lower than the upper limit permitted for individuals. On page 9 of the BEIR Report, the NAS expands on this issue. In discussing the current PAGs, the following paragraphs are presented.

> "A major difficulty has been the misinterpretation of these standards, particularly in the public mind. The intent as stated is that no individual in the general population should receive whole-body exposure of more than 0.5 rem/year and that the average exposure of population groups should not exceed 0.17 rem/year. What is often not realized is that one or the other limits may be governing depending on the nature of exposure. For example, if the exposure were to arise from specific locations such as nuclear power plants or reprocessing plants and it were assured that no individual at the boundaries of the installations could be exposed to more than 0.5 rem/year, it would be physically impossible for the U.S. population averages to approach anywhere near the level of 0.17 rem/year from such sources. Accordingly, we feel (disregarding numerical values) that both individual and the average population guidelines should be maintained but that clarification should be included as the integral part of the regulatory statement."

> "In addition to individual and average population guidelines, we recommend that an additional limitation be formulated (not as a basic standard but for generating guidance) that takes into account the product of the radiation exposure and the number of persons exposed: this might be expressed in terms of person-rems. This need arises from acceptance of non-threshold approach in risk estimates which implies that absolute harm in the population will be related to such a product. Operationally, for example, there would be advantage in assessment of trade-offs

> in connection with the siting of nuclear installations as related to the population of areas under consideration.
>
> "The above recommendations could be implemented with present knowledge. We now come to an important area that requires newer approaches. *It is suggested that numerical radiation standards be considered for each major type of radiation exposure based upon the results of cost-benefit analysis*. As a start, consideration should be given to exposure from medical practice because of present relatively high levels of exposure and from nuclear power development because of future problems of energy production and the need for public understanding.
>
> "The difficulties in attaining a useful cost-benefit analysis for nuclear power are formidable and will require interdisciplinary approaches well beyond those that have yet been attempted. Areas that require evaluation include: (a) projection of energy demands, (b) availability of fuel resources, (c) technological developments (clean combustion techniques, coal gasification, breeder reactors, fusion processes, magnetohydrodynamics, etc.), (d) public health and envrionmental costs of electrical energy production from both nuclear and fossil fuel including aspects of fuel extraction, conversion to electrical energy, and transmission and distribution."

We have underlined statements which we believe are important in characterizing the NAS concerns and suggestions. We find the observation that if the near individual is limited to not more than 0.5 rem/year, it is physically impossible for the U.S. population averages to approach the level of 0.17 rem/year. Clearly, NAS is stating that item (d) is satisfied for exposures arising from specific locations. NAS recommends limiting the population annual exposure in terms of person-rem/year, *not as a basic standard but for guidance*. The only feature of the EPA proposed standard which relates to limiting the population annual exposure is the limit on the amount of long lived material released. In this case EPA has expressed the limits in terms of curies per MWe quantities, *but in effect this limits the population's annual exposure* by an emission standard rather than a dose guideline -- contrary to the NAS recommendation on two counts.

NAS suggests that numerical radiation standards be considered for each major type of radiation exposure based upon the results of cost-benefit analyses. In the discussion of the difficulties in attaining a useful cost-benefit analysis, it is clear that a broader study than that provided by EPA is required to select the suggested numerical standards. For example, on page 8 of the BEIR Report, NAS cites the lack of data on fossil fuels for cost-benefit analysis.

> "Thus for example, we find relatively little data available on the health risks of effluents from the combustion of fossil fuels. Furthermore, it is becoming increasingly important that society not expend enormously large resources to reduce very small risks still further, at the expense of greater risks than go unattended; such imbalances may pass unnoticed unless a cost-benefit analysis is attempted. If these matters are not explored, the decisions will still be made and the complex issues resolved either arbitrarily or by default since the setting and implementation of standards represent such a resolution."
> (Emphasis added)

This paragraph also is reflected in item (f) of the NAS comments quoted above.

Items (i) and (j) suggest the need for further studies and research to permit more accurate determinations of impact of the proposed EPA standard. We believe that there is substantial progress toward satisfying this need but much more effort is needed and it is in this area that we believe coordinated efforts among the several government agencies and the nuclear industry is needed.

In summary, we see no admonition in the BEIR Report that the current RPGs should be substantially reduced as proposed by EPA. Rather, we see suggestions to more accurately characterize radiological impact so that potential problems may be identified and prevented.

The FRC, having defined the general framework for the radiation protection requirements, recognized that detailed standards could best be developed by the Federal agencies with immediate knowledge of the design and operating characteristics. This is clearly stated in the seventh recommendation of the FRC which was approved by the President [FR Doc. 60-4539, May 8, 1960, p. 4403].

> "7. The Federal agencies apply these Radiation Protection Guides with judgement and discretion, to assure that reasonable probability is achieved in the attainment of the desired goal of protecting man from the undesirable effects of radiation. The Guides may be exceeded only after the Federal agency having jurisdiction over the matter has carefully considered the reason for doing so in light of the recommendations in this paper.
>
> The Radiation Protection Guides provide a general framework for the radiation protection requirements. It is expected that each Federal agency, by virture of its immediate knowledge of its operating problems, will use these Guides as a basis upon which to develop detailed standards tailored to meet its particular requirements. The Council will follow the activities of the Federal agencies in this area and will promote the necessary coordination to achieve an effective Federal program."

It is our view that EPA is proposing to promulgate the detailed standard referenced above rather than the general framework for radiation protection. In today's terminology, we believe that the proposed standard does not meet the definition of a "generally applicable environmental standard" but more nearly represents a "detailed standard" with elements of "emission control standard" which are better left to other agencies with a more immediate understanding of the design and operating characteristics of the facilities.

ATTACHMENT B

EFFLUENT REGULATION BY THE NUCLEAR REGULATORY COMMISSION

The commercial use of atomic energy was the first technology to be subject to comprehensive Federal regulatory control from its inception. Under the Atomic Energy Act of 1954, as amended, no person may construct or operate a nuclear facility, such as a nuclear power plant or nuclear fuel reprocessing plant, or possess or use source, byproduct, or special nuclear materials except as authorized by an NRC permit or license. In addition, the Atomic Energy Act authorizes the NRC to promulgate regulations specifying design, siting, and operating requirements for nuclear facilities to protect against possible radiation hazards arising from normal operations. The Act requires the NRC to set limits on the amounts of radioactive material that may be released during normal operations of nuclear facilities and other activities involving nuclear materials.

Under the Atomic Energy Act the NRC has a comprehensive regulatory program involving licensing, standard setting, inspections, and enforcement. Detailed regulations concerning siting, design, and other aspects of regulation of nuclear facilities and activities have been published in 10 CFR Chapter 1. In addition, we have issued more than 200 Regulatory Guides to provide guidance on methods acceptable for implementing specific parts of the Commission's regulations, to delineate techniques used in evaluating specific problem areas, and to provide other guidance to applicants and licensees.

Implementation of Radiation Protection Standards

Since its inception, the AEC, and now the NRC, has looked to the published recommendations of the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP) for guidance in the formulation of rules and safety requirements in regulation of the nuclear power industry. In addition, in 1959 the Atomic Energy Act was amended to establish the Federal Radiation Council (FRC), whose function was to advise the President on radiation matters affecting health, including guidance for all Federal agencies in the formulation of radiation standards.

All functions of the Federal Radiation Council were transferred to the Administrator of the Environmental Protection Agency (EPA) by Reorganization Plan Number 3 of 1970. Also transferred to EPA by this Plan were "The functions of the Atomic Energy Commission under the Atomic Energy Act of 1954, as amended, administered through its Division of Radiation Protection Standards, to the extent that such functions of the Commission consist of establishing generally applicable environmental standards for the protection of the general environment from radioactive material. As used herein, standards mean limits on radiation exposures or levels, or concentrations or quantities of radioactive material, in the general environment outside the boundaries of locations under the control of persons possessing or using radioactive material." The NRC retained the responsibility for implementation and enforcement of EPA standards.

In its first Memorandum for the President dated May 13, 1960, the FRC recommended adoption of Radiation Protection Guides for Federal use in normal peacetime operations. Subsequently, additional radiation protection guides were recommended and adopted in Reports No. 2 and 8. Current NRC regulations conform to the FRC guidance to Federal agencies approved by the President. EPA has not altered the guidance issued by the Federal Radiation Council and the Commission's regulations remain consistent with FRC guidance to Federal agencies.

The FRC, ICRP, and NCRP guidance includes, but is not restricted to, quantitative radiation protection guides and dose limits. Since any radiation exposure may involve some degree of risk, these standards setting groups also have recommended that radiation doses be kept "as low as practicable" or, as stated by the ICRP, and now contained in NRC regulations, "as low as reasonably achievable, social and economic considerations being taken into account." Therefore, the NRC system of implementing FRC guidance is aimed at the following principal objectives:

1. To keep doses from all sources of radiation exposure, other than natural background and medical procedures, well within the FRC numerical radiation protection guides.

2. To avoid unnecessary sources of exposure and to ensure that doses received are justifiable in terms of benefits.

3. To provide for design and operational control of specific facilities and uses of materials, both individually and in combination, so that the resulting doses are sufficiently low that any further reduction in risk would not be considered to justify the effort required to accomplish it; that is, the doses are as low as reasonably achievable.

These objectives are achieved by:

1. Establishing and enforcing "regulatory upper limits" on doses and releases of radioactive material to the environment applicable to all licensed activities. These limits are not intended to be exceeded. They are set forth in the Commission's regulation, 10 CFR Part 20, "Standards for Protection Against Radiation."

2. Establishing and enforcing design objectives and limiting conditions of operation applicable to specific classes of nuclear facilities and uses of radioactive material to assure that persons engaged in activities licensed by the NRC make every reasonable effort to maintain radiation doses and releases of radioactive material in effluents to the environment as far below the regulatory upper limits as is reasonably achievable.

This approach to design objectives and limiting conditions of operation implies a cost-benefit methodology with emphasis on the differential in costs and benefits that might be involved in requiring the activity to be carried out at one level of exposure rather than another.

We believe that the application of this regulatory process, with emphasis on design criteria, operating procedures, and effluent monitoring, effectively controls releases of radioactive material and assures that the risk from exposure to radiation resulting from normal operations of the nuclear power industry is kept at an extremely low level.

We also believe that this approach to regulation is highly responsive to the recommendations of the Advisory Committee on the Biological Effects of Ionizing Radiation, National Academy of Sciences, as reflected in their November 1972 report on "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation" (BEIR Report). Chapter II of the report, "Needs of the Times," emphasizes the need for quantifying risk and the use of cost-benefit analyses in decision-making. The report very wisely points out that this methodology brings into the decision-making process such important considerations as whether the public interests are better served by spending our limited national resources on health gains from reducing radioactive contamination or by spending for other societal needs.

NRC Experience in Implementing the "As Low As Reasonably Achievable" Concept

The effectiveness of the implementation of the "as low as reasonably achievable" concept in the regulatory process is confirmed by experience in the nuclear industry. This experience shows that licensees have generally kept releases of radioactive material in effluents at such low levels that resultant exposures to persons living in the immediate vicinity of nuclear facilities have been much less than the FRC radiation protection guides for individual members of the public. The Nuclear Regulatory Commission has published numerical guidance on design objectives and limiting conditions of operation for light-water-cooled nuclear power reactors in Appendix I to its Part 50 regulations. This regulation was the subject of extensive public rulemaking hearings, including a detailed environmental statement with extensive cost-benefit analysis. Conformance with the guides on design objectives and limiting conditions of operation provides reasonable assurance that annual total body doses to individuals living near the boundary of a reactor site will be a small fraction of existing radiation exposure limits.

PART III

J. TESTIMONY OF AMC AT NRC HEARINGS IN DENVER, COLORADO (OCTOBER 1 AND 2, 1979) AND ALBUQUERQUE, NEW MEXICO (OCTOBER 18 AND 19, 1979)

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ESIDENT

TESTIMONY ON BEHALF
OF
THE AMERICAN MINING CONGRESS
AT THE
NUCLEAR REGULATORY COMMISSION
HEARINGS ON THE
DRAFT GENERIC ENIRONMENTAL IMPACT STATEMENT ON URANIUM MILLING
(NUREG-0511)
IN
DENVER, COLORADO

October 1 and 2, 1979

Prepared by the AMC Uranium Environmental Subcommittee

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TESTIMONY OF ROBERT G. BEVERLY

On Behalf of the American Mining Congress
At The Nuclear Regulatory Commission's
Hearings on the
Draft Generic Environmental Impact
Statement (Draft GEIS) on
Uranium Milling
And on the
Associated Proposed Regulation Changes

Good morning, Mr. Chairman and members of the hearing panel. My name is Robert G. Beverly. I am Director of Environmental Controls for the Metals Division of Union Carbide Corporation. My business address is Box 1029, Grand Junction, Colorado. With me today to testify are Mr. Michael J. Taylor of D'Appolonia Consulting Engineers and Mr. R. Stephen Schermerhorn of Impact Environmental Associates.

The three of us are testifying today on behalf of the American Mining Congress. The AMC is a trade association whose membership includes over 500 companies actively involved in exploration, development and production of the essential minerals and fuel resources vital to our Country's continued prosperity and national security.

Our membership includes most of the U.S. companies currently producing or expected to produce uranium ore concentrate to meet our present and future needs. Uranium ore concentrate, known as "yellow cake," is the basic raw material from which fuel rods are made for nuclear power plants. Nuclear power currently provides approximately 13% of our national electric energy demands and in some regions, such as New England and the Chicago area, nuclear fuel from uranium yellow cake is relied on for as much as one-half of the regional electric power supply.

We are not here, however, to debate the importance of nuclear power to our society. The fundamental need for nuclear power on a continuing basis for the foreseeable future has been well-established in other forums.

What we *are* here to discuss are regulatory proposals which will certainly affect the uranium mining and milling industry's ability to continue to provide the secure, domestic supply of yellow cake essential to our society. Let me make it clear beyond doubt at the outset that the American Mining Congress does *not* oppose reasonable regulatory controls. AMC recognizes that government at all levels--federal, state, and local--has a legitimate and important interest in the nuclear fuel cycle. Indeed, over many years AMC has actively participated with governmental agencies to develop reasonable and effective public health and safety and environmental protection regulations. While we have not always agreed totally with the controls finally promulgated, we have continued to work with government toward our common goal of a rational regulatory regime which carefully balances *all* of our society's interests. It is in this spirit of continued cooperation that we welcome the opportunity today

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to share with this hearing panel and the public some of our thoughts concerning needed improvements and alterations in the draft Generic Environmental Impact Statement on Uranium Milling and in the proposed amendments to the mill licensing regulations.

The AMC will be presenting testimony at both today's hearing and at the hearings scheduled for October 18th in Albuquerque. We will also be submitting detailed written comments for consideration by the Commission. We have divided our oral presentation between today's hearing and the Albuquerque hearing so as to minimize overlap in our testimony.

I will be discussing AMC's basic conclusions about the draft GEIS and some general recommendations for change not only in that document but in the approach and timing of the proposed regulations as well. Mr. Taylor will next present our views on the conclusions and recommendations set forth in the proposed regulations and the draft GEIS regarding groundwater protection aspects of uranium mill tailings disposal methods. Our third speaker, Mr. Schermerhorn, will address the dispersion and dosimetry code used in the draft GEIS. This Code is known as the UDAD Code.

At the Albuquerque hearing, Mr. Langan Swent, Vice President of Homestake Mining Company, will be the principal spokesman for AMC. He will address the portions of the

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draft GEIS which discuss impacts from milling, estimated costs, decommissioning requirements and also the need for a cost effectiveness analysis. Also testifying with Mr. Swent will be Dr. Keith Schiager of ALARA, Inc., Dr. Bernard Cohen, a nuclear health physicist at the University of Pittsburgh, and two other AMC representatives.

Dr. Schiager will address radiological effects associated with uranium mills, with emphasis on radon emissions from tailings.

Dr. Cohen will discuss the health risks presented in the draft GEIS and place those risks in perspective relative to risks each of us faces in our daily activities. For instance, some of the members of this hearing panel undoubtedly traveled to Denver from Washington, D.C., on a jet. The accident risk for that flight was 25 times greater than the annual individual radiation risk from <u>all</u> the 82 predicted model mills without the proposed controls. Dr. Cohen will discuss these calculations with the hearing panel in Albuquerque.

I will confine my remarks today to the following subject areas:

1. AMC's Basic Conclusions Concerning the Draft GEIS and the Proposed Regulations;
2. The Need for More Flexibility in the Proposed Regulations; and
3. The Premature and Potentially Conflicting Nature of the Proposed Regulations.

AMC's Basic Conclusions Concerning the Draft GEIS and the Proposed Regulations

NRC states that its purpose in undertaking preparation of the GEIS is to assess the environmental impacts of uranium milling operations and to determine what, if any, changes are required in its regulations covering these operations. Particular emphasis is placed on mill tailings disposal and mill decommissioning. Any necessary regulatory changes, now proposed as twelve licensing criteria, are to be based on and supported by data and analysis in the GEIS. The need for each discrete regulatory action should be presented as well as the expected effect of each such action. Our basic conclusion, however, is that the draft GEIS does not demonstrate a need for the particular regulatory changes proposed.

Nowhere in the draft GEIS is there any explanation of how or why the numerous specific requirements were selected. The NRC wants tailings covered with 3 meters of material; why not 1 meter or some other value? There is a proposed requirement of a calculated rate of 2 pCi/m^2--sec for radon emanation; why not 10 or 50 picocuries or some other value? If these requirements have a sound scientific basis, it should appear in the GEIS; yet it does not.

The GEIS appears to provide little more than an analysis of the effects of implementing previously conceived

NRC staff positions and NRC Regulatory Guides. Unfortunately, however, these positions and guides were developed prior to the draft GEIS rather than from any scientific conclusions presented in that document. This is not a sound scientific or regulatory procedure.

The Need for More Flexibility In the Proposed Regulations

In view of the enormous diversity of site conditions at existing and future mill sites (a fact which is repeatedly acknowledged in the text of the draft GEIS), the rigidity of the document's major conclusions is of great concern to us. For example, while numerous alternatives are discussed, the draft GEIS basically concludes that: all tailings ponds must be lined and all tailings piles must be covered with a minimum of 3 meters of material. The phrase "site specific considerations" must be more than a repetitive phrase interspersed in the text. It must be a fundamental basis of NRC's regulatory conclusions.

In making reasonable allowance for site specific factors NRC will not be forced to promulgate overly broad criteria that do not provide adequate safeguards for public health and the environment. NRC can and should identify appropriate performance standards, rather than rigid design requirements. Such performance standards should include parameters, guidelines, or ranges to be considered by the industry in designing control methods on a site specific basis.

The draft GEIS comes to unrealistic and inaccurate conclusions about the regulatory requirements for mills and mill tailings disposal. For example, appropriate guidelines for tailings cover should be based on sound, state-of-the-art scientific and engineering evidence which will assure the necessary safeguards to public health. Rigid regulatory criteria may provide an easy answer but seldom an effective one.

The Premature and Potentially Conflicting Nature of the Proposed Regulations

AMC believes NRC is acting prematurely in proposing regulations at this time to cover the various areas identified in the draft GEIS. Doing so now may well have the effect of requiring the uranium milling industry to make major plans and commitments to meet this set of regulations, only to have new standards developed by the Environmental Protection Agency in May, 1980.

The Commission should give additional consideration to Section 275 of the Atomic Energy Act which requires EPA to promulgate standards for the protection of public health, safety and the environment from hazards posed by uranium tailings. After the EPA standards are promulgated, NRC is to issue further rules or regulations to implement the general EPA requirements. For NRC to issue its regulations before EPA promulgates its standards seems to reverse the order that Congress set out in the statute. Further,

TESTIMONY OF MICHAEL J. TAYLOR

Tailings Disposal System Design Related to Seepage In The Nuclear Regulatory Commission (NRC) Generic Environmental Impact Statement For Uranium Milling (GEIS)

My name is Michael Taylor. I am a registered professional engineer in Colorado and several other states. I have worked in tailings management for over 12 years. I am currently employed as Project Manager with D'Appolonia Consulting Engineers and reside at 7546 South Willow Circle, Englewood, Colorado. Our firm has been reviewing those portions of the draft Generic Environmental Impact Statement (GEIS) related to tailings disposal system design and seepage. A 30 page written report of our findings will be presented as part of AMC's written comments.

It is our conclusion that the GEIS does not properly emphasize the site specific nature of protecting groundwater at uranium mill tailings disposal sites. We recommend changing the proposed licensing criteria and draft GEIS conclusions on this issue. A tailings management system for groundwater protection should be selected and designed to minimize to the maximum extent reasonably achievable the movement of toxic materials into the groundwater beyond the mill boundary if such movement would create adverse health

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affects. The selection and design of any particular tailings management system should be based on site specific data.

Criteria 5 of the proposed regulations and Item 6 of Chapter 12 "Proposed Regulatory Actions" of the Generic Environmental Impact Statement indicate that seepage from tailings ponds should be reduced by installation of linings, with provisions for consideration of other methods of disposal by the staff if sufficient site specific data can be gathered. The draft GEIS does not provide support for such a conclusion, and the conclusion is inconsistent with data available within government and industry today.

It is recommended that Criterion 5 and Item 6 of Chapter 12 be changed to indicate that the seepage aspects of tailings management are site specific problems and that no single solution should be required in all cases. The implication in proposed Criterion 5, that lining of a tailings pond will solve all site specific problems associated with groundwater protection, is not appropriate. Reliance on "Maginot Line" type solutions in the form of barrier liners will not provide either the best solution to protect groundwater quality or the best solution from a cost standpoint.

In order to select the most appropriate and effective tailings management design for groundwater protection, the sub-surface, the tailings, and the tailings solution characteristics must be considered. Four key sub-surface elements in this design are (1) the geotechnical, (2) geologic, (3) geochemical and (4) hydrologic site characteristics. If a combination of these factors is favorable at a given site, harmful concentrations of toxic materials can be removed from seeping tailings solutions by natural geochemical action. Liner barriers in such cases are redundant for groundwater protection and only serve to incorporate their disadvantages at such a site: that is (a) they will trap water in the tailings, preventing rapid reclamation and decommissioning; (b) they will necessitate expensive water recycling equipment; or (c) they will cause a large impoundment to exist with a greater potential for escape of large volumes of stored tailings solution.

The draft GEIS indicates, in many places, that the tailings management system selection and design is a "site specific" problem. However, the model site discussed in Chapter 4 does not define all key sub-surface site specific elements. Furthermore the alternatives for tailings disposal in Chapter 8, the assessment of impacts in Chapter 6, and the conclusions in Chapter 12 do not properly emphasize the site specific nature of the problem. Rather, barrier liners and the below grade-near surface disposal are stressed and evaluated. The draft GEIS does not discuss the potential adverse effects of liners or tailings storage closer to the groundwater in below grade-near surface disposal.

Indeed, groundwater protection is recognized as a site specific problem, but is not treated as such in the assessments, conclusions and proposed regulations.

As Mr. Beverly has pointed out, this is an example of an area where more flexible guidelines are necessary. Other methods exist, or could be developed, to make the system selection more site specific. A basic evaluation of the various tailings area preparation methods as compared to various typical site subgrade conditions (as set forth in my written comments) shows the variable nature of the solution to tailings disposal system selection and design for groundwater protection. Guidelines should be developed for the types of systems to be considered for various site conditions which will allow use of site specific data.

Since the problem is site specific, the following new Criterion 5 in the proposed regulations and Item 6 Chapter 12 in the draft GEIS is recommended:

> The specific method or combination of methods of the tailings disposal system for mitigating toxic material migration must be worked out on a site specific basis. The system should be selected and designed to minimize, to the maximum extent reasonably achievable, the movement of toxic materials into the groundwater beyond the mill property boundary if such movement would create adverse health affects. Liners may be appropriate in some cases to protect groundwater quality and inappropriate in others. For instance, where natural soils provide an effective barrier against migration of harmful concentrations of toxic materials into or through the groundwater beyond

> the mill property boundary, barrier liners will not be required. Site specific tests and analysis shall be provided as appropriate to assess the impact of the proposed tailings disposal system and allow the staff to evaluate the effectiveness and benefits of the proposed system.

The proposed new criterion and change in the draft GEIS would make tailings disposal consistent with the common NRC and uranium industry objective of protecting groundwater quality, and will also provide a prudent scientific approach to tailings disposal system selection and design.

TESTIMONY OF R. STEPHEN SCHERMERHORN

Use of the Uranium Dispersion And Dosimetry Code (UDAD)
In the Nuclear Regulatory Commission (NRC)
Generic Environmental Impact Statement
for Uranium Milling (GEIS)

My name is R. Stephen Schermerhorn, I am a registered professional engineer and certified consulting engineer in Colorado and several other states. I am currently employed as President of Impact Environmental Consultants and reside at 7004 South Columbine Way in Littleton, Colorado. Since the introduction of the Uranium Dispersion And Dosimetry Code (UDAD), our firm has been examining it to determine its accuracy. We were asked to present our conclusions on the effectiveness of the UDAD Code in evaluating uranium milling impacts in the draft Generic Environmental Impact Statement (GEIS). The written testimony will include a 40 page report containing detailed discussion of this subject.

The UDAD Code has been used in the GEIS to calculate individual and population dose equivalents for receptors near the model mill for a variety of operational scenarios. It has also been used to compare the effectiveness of alternative long term tailings control methods. The UDAD Code is used to calculate dose estimates which are then converted to health risk estimates.

Because of the complex processes involved in radionuclide transport from mills to surrounding areas a representative computer simulation model is warranted to analyze mill radiological impacts for licensing purposes. The UDAD Code provides a good rough draft from which to develop just such a tool. However, both the Code (in all of the evolutionary versions we have reviewed) and its successor MILDOS make too many assumptions to be used as NRC has attempted in the draft GEIS--to precisely evaluate the radiological impacts of uranium mills. Therefore, UDAD Code predictions should not be used as a basis for making regulatory judgments on facility acceptability. Such judgments apparently have been made in the draft GEIS and in the review of individual mill applications.

Further, because of the generic approach of the draft GEIS, its use of the UDAD Code incorporates many standard input parameters for all mills. This is unfortunate. Due to geographical diversity and engineering design differences many site specific parameters exist for any mill. The model which is finally developed must be flexible enough to incorporate site specific data.

In analyzing the UDAD Code we have carefully examined the logic, mathematics and interrelationships of each individual submodel within the Code. The primary documentation reviewed included Appendices to the draft GEIS, and Argonne

National Laboratory materials. In addition, dozens of source documents, dealing with the basic research which led to major assumptions in the UDAD Code, were analyzed to establish whether proper scientific methodology was used.

As a result of these studies, we have arrived at two principal conclusions. First, most of the submodels of the UDAD Code contain, and in some cases obscure, areas of great statistical uncertainty. This uncertainty partly derives from the complexity of the processes being modeled and partly from reliance on insufficiently conclusive baseline research. Usually, where substantial uncertainty was identified, conservative assumptions were made to assure that concentrations or doses were not underestimated.

The second conclusion is that several of the techniques used in the UDAD Code are not representative of the state-of-the-art for modeling specific processes. To cite an example, the UDAD Code air quality submodel is based on Gaussian dispersion assumptions. Government and private studies of predictions made with Gaussian models have demonstrated that they result in concentration overestimates (by as much as a factor of eight under low wind speed conditions), a factor of two to fifteen in moderate terrain and even more when applied in complex terrain. The particulate deposition model used in the UDAD Code has been shown to overestimate concentrations at near receptors by as much as a factor of four. Assumptions concerning deposition velocities do not accurately reflect the physical processes involved.

Methods for calculating source terms are poorly formulated due to arbitrary assumptions, lack of process understanding, and improper interpretation of scientific baseline information. The submodel used for calculating the dust flux from tailings has been applied incorrectly. Assumptions and methods for characterizing the particle size distribution from each of the sources are not consistent with actual particle physics. Precise characterization of size distribution is critical in attempting to accurately calculate inhalation doses.

Ground concentrations are calculated based on conservative assumptions relative to resuspension processes and weathering rates. In calculating ground concentrations a 50-year weathering half-life is assumed for all radionuclides. However, available data indicate a range of values for specific radionuclides which suggest an average value of six months to one year would be more appropriate.

The submodel used in the UDAD Code to calculate vegetation concentrations has been stated by Oak Ridge National Laboratory to be conservative by an order of magnitude. The milk and meat concentration submodels are similarly derived and, in fact, depend upon the vegetation model for input.

The submodels used for dose calculations are generally the best available and are based on relatively nonconservative assumptions. The exception is the external dose model which can overestimate doses at near receptors by one or two orders of magnitude.

Reliance on the UDAD Code is inappropriate since several submodels are outmoded. It is made even more inappropriate because inaccurate and conservative assumptions have been made in many subroutines.

When the conservative results of one submodel are used as input to other similarly conservative submodels the conservatism is compounded. As an example, considering only those submodels for which overestimations have been quantified, the dispersion submodel overestimates by a factor of 2 to 15, the deposition submodel overestimates by a factor of 2 to 4, and the external dose submodel overestimates by an order of magnitude. The result is that external dose equivalents at near receptors are overestimated by a factor of 40 to 600. I think it is fair to state that the use of the UDAD Code will result in grossly exaggerated radiological levels.

The precise degree of uncertainty inherent in each of the UDAD Code's submodels has not been quantified. Nor has each submodel's effect on the final value derived from UDAD been examined. Although to do so would require additional specific studies, we believe such studies are necessary.

We offer the following recommendations:

1. Until revisions are made the UDAD Code should not be used. This is true both for the individual applications and for use in the draft GEIS. UDAD Code predictions should not be used for developing or enforcing regulations.

2. A sensitivity analysis of the UDAD Code should be conducted. Further research is needed to improve the accuracy of many of the submodels. These research needs have been extensively discussed by experts in the field. However, to our knowledge, no priorities for granting research funds have been established.

3. Finally, even a representative computer simulation model must be continually updated and revalidated to reflect advances in the state-of-the-art.

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TESTIMONY ON BEHALF
OF
THE AMERICAN MINING CONGRESS
AT THE
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HEARINGS ON THE
DRAFT GENERIC ENVIRONMENTAL
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IN
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October 18 and 19, 1979

Prepared by the AMC Uranium Environmental Subcommittee

TESTIMONY OF LANGAN W. SWENT

On behalf of the American Mining Congress
at the Nuclear Regulatory Commission's Hearings
on the Draft Generic Environmetal Impact Statement
(Draft GEIS) on Uranium Milling
and on the
Associated Proposed Regulation Changes

Good morning, Mr. Chairman and members of the Hearing Panel My name is Langan W. Swent. I am Vice President of Engineering for Homestake Mining Company. My business address is 650 California Street, San Francisco, California. I have been involved actively in uranium mining and milling since 1955. From 1957 through 1966 I was General Manager of Homestake-Sapin Partners (now renamed United Nuclear-Homestake Partners) which operated four underground uranium mines and a 3500 ton per day alkaline leach uranium mill. Since late 1966, I have been in our San Francisco corporate headquarters with continuing active responsibility in uranium mining and milling.

With me today to testify are Dr. Keith J. Schiager of ALARA, Inc., Dr. Bernard L. Cohen of the University of Pittsburgh, Mr. Gordon T. Swanby of Atlas Minerals, and Dr. Harrison B. Rhodes of Union Carbide Corporation.

The five of us are testifying today on behalf of the American Mining Congress. The AMC is a trade association with a membership of over 500 companies actively involved in exploration, development and production of the essential minerals and fuel resources vital to our country's continued prosperity and national security.

Our membership includes most of the U. S. companies currently producing or expected to produce uranium ore concentrate to meet our present and future needs. Uranium ore concentrate, known as "yellowcake" is the basic raw material from which fuel rods are made for nuclear power plants. Nuclear power currently provides approximately 13% of our national electric energy demands and in some regions, such as New England and the Chicago area, nuclear fuel from uranium yellowcake is relied on for as much as one-half of the regional electric power supply.

We are here to discuss regulatory proposals which will certainly affect the uranium mining and milling industry's ability to continue to provide the secure, domestic supply of yellowcake essential to our society. Let me make it clear beyond doubt at the outset that the American Mining Congress does not oppose reasonable regulatory controls. AMC recognizes that government at all levels--federal, state and local--has a legitimate and important interest in the nuclear fuel cycle. Indeed, over many years, AMC has actively participated with governmental agencies to develop reasonable and effective public health and safety and environmental protection regulations. While we have not always agreed totally with the controls finally promulgated, we have continued to work with government toward our common goal of a rational regulatory regime which carefully balances all of our society's interests. It is in this spirit of continued cooperation that we welcome the opportunity today to share with this Hearing Panel and the public some of our thoughts concerning needed improvements and alternatives in the draft Generic Environmental Impact Statement on Uranium Milling and in the proposed amendments to the mill licensing regulations.

In addition to presenting testimony at today's hearings, the AMC presented testimony at the October 1st hearing in Denver. We will also be submitting detailed written comments for consideration by the Commission. We have divided our oral presentation between today's hearing and the Denver hearing so as to minimize overlap in our testimony.

In Denver, Mr. Robert G. Beverly of Union Carbide Corporation, Mr. Michael J. Taylor of D'Appalonia Consulting Engineers, and Mr. R. Stephen Schermerhorn of Impact Environmental Associates testified on behalf of AMC. Mr. Beverly testified that whereas NRC's stated purpose in undertaking the GEIS is to assess environmental impacts of uranium milling and determine what, if any, new regulations are required, the draft GEIS fails to achieve this purpose since it lacks any demonstration of a need for the particular regulatory changes proposed. Instead, the draft GEIS provides little more than an analysis of the effects of implementing previously conceived NRC staff positions and

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NRC Regulatory Guides. Mr. Beverly also outlined a number of general recommendations for change, not only in that document but in the approach and timing of the proposed regulations as well.

Mr. Taylor discussed AMC's conclusions and recommendations with respect to defects in the GEIS' treatment of the groundwater protection aspects of uranium mill tailings disposal methods. Our third Denver speaker, Mr. Schermerhorn, addressed serious shortcomings in the dispersion and dosimetry code used in the draft GEIS and referred to as the UDAD code.

This morning, I am going to confine my remarks to pointing out the gross exaggerations of radiological risk in the draft GEIS. Dr. Schiager will discuss significant errors in the draft GEIS' assessment of radon emanation and its impact on public health. Following this, Mr. Swanby will discuss some of the significant cost underestimates in the draft GEIS. Then Dr. Cohen will place radiation risks from uranium milling in proper perspective in relation to risks for various daily life activities, and will discuss factors which should be considered in any cost-effectiveness analysis. Finally, Dr. Rhodes will discuss the need for cost-effectiveness analysis and the results of this type analysis on tailings cover depth.

I will discuss the grossly exaggerated potential radiological impact on public health and safety attributed to uranium milling processes in the draft GEIS.

The draft GEIS professes to rely on potential adverse radiological effects to justify its two most rigid regulatory proposals. Specifically, these proposals are the radon flux limit of 2 pCi/m^2-sec and the minimum cover requirement of three meters for tailings. It is clear, however, that these proposals are based on NRC's preconceived notions rather than any scientific analysis of risks. That this is the case is particularly clear when the data and methods employed in the draft GEIS are examined.

The exaggeration of radiological risks in the draft GEIS is both pervasive and cumulative. There are four primary areas of overestimation. These occur consecutively, with the result that each overestimation is multiplied by each of the succeeding overestimations.

The first overestimate is in the projected U. S. nuclear generating capacity to be operating by the year 2000. The draft GEIS relies on a 1977 ERDA report which projects 380 billion watts. This has been superseded by a 1978 DOE estimate of 255 billion watts. This means that approximately 50 model mills would be required in the year 2000 instead of the 82 mills predicted in the draft GEIS. Stated another way, this means that the GEIS' overestimate of the demand for nuclear power in the year 2000 directly results in a risk overestimate factor of about 1.5.

The second major overestimation of risks stems from the assumptions used to analyze the effects of the model mill, especially the assumptions in the UDAD code. This computer code is used to predict the intensity of radiological effects at various distances from the model mill sites. Mr. Schermerhorn testified in Denver on the overestimations inherent in a number of the submodels which collectively make up the UDAD code. The errors in the various submodels of the UDAD code are compounded so that the dispersion calculations overestimate concentrations by a factor of 2 to 15. The inherent overestimation by the UDAD code, of course, has the effect of geometrically increasing the initial overestimation of risk caused by assuming there will be 82 model mills, bringing the total overestimation factor at this point to a range of 3 to 22.

The third overestimation of risks results from misapplication of data contained in the BEIR Report in estimating the health effects that would be caused by the radiological impacts predicted by the UDAD Code. This misapplication of BEIR Report data is a result of miscalculating risk factors, making incorrect assumptions on matters such as smoking habits, ignoring the extended latent-induction periods resulting from low radiation dosages, failing to account for the effect of competing causes of death, and overstating the occupancy of areas near the mill site. These factors all combine to further overestimate, by a factor of 5 to 7, the health effects among the public which would result from the grossly exaggerated radiation effects predicted by assuming 82 model mills and using the UDAD code. The compounded factor of overestimation at this point becomes 15 to 150.

The fourth major overestimation results from the application of incorrect factors derived from BEIR Report data. Dr. Schiager will point out how extrapolation of data on health effects from the high exposures to radon and other carcinogens to determine the health effects of very low exposures to radon results in a further overestimation of risk to the public by a factor of 20 to 40. The final compounding of these four major overestimates results in an overall overestimate of public health effects by a factor ranging from 300 to 6,000.

At this time, I would like to introduce our next speaker, Dr. Keith Schiager.

TESTIMONY OF KEITH J. SCHIAGER

On behalf of the American Mining Congress
at the Nuclear Regulatory Commission's Hearings
on the Draft Generic Environmental Impact Statement
(Draft GEIS) on Uranium Milling
and the
Associated Proposed Regulation Changes

Mr. Chairman and members of the Hearing Panel: My name is Keith Schiager and I am an independent consultant on radiation protection. I am the president of ALARA, Inc., located in Lyons, Colorado. I have spent the past 23 years in the health physics profession, and since 1965 I have been extensively involved with the evaluation and control of radon exposures to uranium miners and the general public. Most of my professional career has been spent in national laboratories and educational institutions as a researcher and teacher. My most recent full-time academic appointment was with the University of Pittsburgh as Professor of Health Physics. My consulting clients are predominantly government agencies and major government contractors (1) with a smaller number of industrial clients.

My testimony today is directed to the proposed maximum radon emanation rate of 2 pCi/m^2-sec for reclaimed tailings piles. This proposed limit is inconsistent with accepted

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(1) e.g., U.S. Bureau of Indian Affairs, U.S. Bureau of Mines, U.S. Geological Survey, U.S. Environmental Protection Agency, Bendix Field Engineering Corporation and Oak Ridge National Laboratory (both DOE contractors), the USPHS Center for Disease Control, etc.

standards for radiation protection. It is not based on physical or biological data, but rather on philosophical judgments of the NRC staff. The attempts to justify this proposed limit are based on erroneous assumptions and misinterpretations of the evidence relating to normal background radon emanation rates and to the health risks resulting from inhalation of radon and its decay products.

Legitimate criteria for limitation of radiation doses, as developed and accepted by the national and international scientific community, are the limitation of exposure to any individual and the total health risk to populations. Individual exposure limits (2) for radon are readily satisfied in most cases with little or no covering of tailings piles. Since there is no recommended or regulatory limit for population exposures, this criterion must be based upon the principle that all exposures should be reduced to levels that are as low as reasonably achievable (ALARA) taking into consideration all relevant social and economic factors. This principle obviously demands a detailed cost-benefit analysis that includes all future costs as well as future benefits. These criteria have been ignored in the

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(2) The current concentration limit for radon-222 in unrestricted areas resulting from releases from a licensed facility is 3 pCi/L above natural background (10 CFR 20). This limit is reduced to 1 pCi/L if a "suitable sample of the population" is exposed. The "suitable sample of the population" is not defined, but it is usually interpreted to mean communities of at least a few hundred or thousands of people, which would be likely to contain a representative distribution by ages and health conditions.

development of the proposed limit and seriously misconstrued in the effort to justify it.

The primary benefit of the proposed radon control measures is presented in the draft GEIS as the prevention (3) of 9,800 cases of lung cancer to the year 3,000 or about 10 cases per year. This calculated number of lung cancer cases attributable to the radon emissions from uncontrolled tailings piles is grossly exaggerated and results in an unrealistic assumption of the benefits of the proposed control measures. The calculation is based on the linear, non-threshold model of biological effects and on the risk estimates used by the BEIR Committee (4).

The BEIR Report included calculations of both absolute and relative risk values. Absolute risk (5) is simply the number of cases that would be produced per unit population exposure. The use of absolute risk values implies that each increment of exposure will produce the same total biological effect (e.g., cases of lung cancer) regardless of the actual level of exposure or the presence of other carcinogens. The absolute risk model is, therefore, the only truly linear model for the dose-response

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(3) According to the draft GEIS, by reducing the emission rate to 2 pCi/m^2-sec above the natural background rate, the premature cancer deaths from this source would be reduced to 42 in the same 1000-year interval (page 12-12).

(4) Advisory Committee on the Biological Effects of Ionizing Radiation, The Effects on Populations of Exposure to Low Levels of Ionizing Radiation, National Academy of Sciences-National Research Council, 1972.

(5) Absolute risk is defined in the BEIR Report as the "product of assumed relative risk times the total population at risk; the number of cases that will result from exposure of a given population."

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relationship. However, recent analyses (6,7) of lung cancer incidence among uranium miners indicate that the relative risk model best describes the data.

Relative risk(8) is derived from the ratio of observed to expected cases in the populations studied. The use of a ratio implies that each added increment of exposure will produce the same percentage increase in biological effects above those that would occur at the next lower level of exposure. For example, if a relative risk of 1.05 per unit dose is derived from a population with a normal cancer incidence of 400 per million per year, the calculated number of excess cases per unit dose is 20 per year. However, if the same relative risk is applied to a population with a normal cancer incidence of 10 per million per year, the calculated number of excess cases per unit dose will be only 0.5 per year. The dose-response curve is approximately linear only for small differences in exposures and only when all other contributing factors remain constant. A linear extrapolation from the uranium miners' data to general populations using relative risk estimates is totally unjustified.

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(6) Ellett, W. H., Exposure to Radon Daughters and the Incidence of Lung Cancer, presented at the American Nuclear Society meeting in San Francisco, CA, December 1, 1977.

(7) Archer, V. E., E. P. Radford, and O. Axelson, Radon Daughter Ca in Man: Factors in Exposure-Response Relationships, presented at the Annual Meeting of the Health Physics Society, Minneapoli MN, June 1978.

(8) Relative risk is defined in the BEIR Report as "the ratio of the risk in those exposed to the risk to those not exposed, or incidence in exposed population to incidence in control populations."

Recent discussions (7,9) of lung cancer risk emphasize the initiator-promoter model of carcinogenesis (10), possibly requiring sequential actions on a susceptible cell in which the second action is conditional upon the first action having been completed. This model can account for the fact that lung cancer has increased from approximately 10 per year per million population in the early part of the this century to more than 400 per year per million population today. This increase was obviously not due to changing environmental radon concentrations. The current lung cancer incidence rate upon which relative risk calculations are based is the result of these recent exposures to other carcinogens, e.g., tobacco smoke and photochemical smog. If the impact of exposures to radon from uranium mills is calculated on the basis of future projections for cleaner air and lower cigarette consumption, comparable to conditions existing early in the century, the projected number of premature cancer deaths

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(9) Brodsky, A., A Stochastic Model of Carcinogeresis Incorporating Certain Observations from Chemical and Radiation Dose-Response Data, Health Physics 35:421, June 1976.

(10) This model can account for the observed non-linearity of the dose-response curve for certain kinds of radiation exposures and observed cancers. For example, it can account for the observation (7) that the risk of lung cancer to uranium miners appeared to increase when the same total exposure was received over longer periods of time.

occurring during the next 1000 years would be about 250 for the base case with no covering of tailings, or one-fourth of one premature cancer death per year.

The authors of the GEIS obtain an unrealistically high estimate of the benefit of radon control by averaging the absolute and relative risk estimators derived from uranium miners and treating this average as an absolute risk applicable to all populations at all future times. They have ignored the recent evidence that indicates that lung cancer can be best described by the relative risk model, and they have ignored the important implications and proper application of the relative risk model.

The proposed radon emission criterion of 2 pCi/m^2-sec is not based upon either the necessary protection of individuals or on considerations of public health risks. Instead, it is based upon "the objective of returning tailings disposal sites to conditions which are reasonably near those of surrounding environs" (page 17). Using this objective "eliminates the option of controlling radon at much higher levels, such as 10-100 pCi/m^2-sec, since background flux rates average between about 0.5 and 1.0 pCi/m^2-sec" Elsewhere (page 12-10 and Appendix 0) the average radon flux is assumed to be 0.5 to 1.3 pCi/m^2-sec, with an upper limit of 3.5 pCi/m^2-sec. These statements illustrate either the misunderstanding or the misuse of environmental data. The authors of the GEIS have averaged out all of the variability of the real world.

I concur with the general objective of leaving tailings piles in such a condition that radon release rates, and the potential for radiation exposures, are within the range of natural background. Such a requirement would assure that present or future generations would not be subjected to risks that are different either in kind or in magnitude from those imposed by nature. This requirement should not imply, however, that all radiation sources under human control must be reduced to the average found in nature. Instead, the impacts of human activities should be compared with the distribution (or range) of comparable impacts from natural sources.

An extremely wide range of concentrations of materials (including radioactivity) is observed in nature. The commercial extraction of various minerals in specific locations is simply one illustration of this fact. No mining company would be in business if the only ore available contained the *average* mineral concentration found in the earth's crust.

Environmental radon sources have been observed to conform to a *log-normal distribution*.(11) By referring to *geometric* mean concentrations of radon (page C-5), the GEIS indirectly acknowledg that radon concentrations are log-normally distributed. However, it ignores that fact when addressing the proposed levels of radon control in relation to natural radon sources and exposures.

The GEIS assumes an average indoor concentration of about 900 pCi/m^3 for western regions (page C-5). This value is derived from an estimate of outdoor radon concentrations in western regions of 240 pCi/m^3 and an extrapolation from indoor-to-outdoor ratios observed in the New Jersey and New York area. Shearer and Sill(12) observed outdoor background radon concentrations

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(11) In a log-normal distribution, 50% of the observed values are greater than or equal to the median value; 15% exceed the median multiplied by the geometric standard deviation (GSD); 2.3% exceed the median multiplied by the *square* of the GSD; 0.13% exceed the median multiplied by the *cube* of the GSD; etc.

(12) Shearer, S. D. and C. W. Sill, *Evaluation of Atmospheric Radon in the Vicinity of Uranium Mill Tailings*, Health Physic 17:77, 1969.

of 800 pCi/m^3 in Grand Junction, 500 pCi/m^3 in Durango, 340 pCi/m^3 in Monticello and 380 pCi/m^3 in Salt Lake City. All of these background concentrations are substantially higher than the 240 pCi/m^3 assumed in the GEIS. Measured indoor concentrations in the United States reported by the NCRP(13) range from 5 to 4800 pCi/m^3; the average values from the 10 studies cited by the NCRP have a geometric mean of 225 pCi/m^3 and a geometric standard deviation of 3.

Measurements of indoor radon progeny concentrations at background locations in Crand Junction made by the Colorado Department of Health(14) exhibited a median value of 0.072 WL with a geometric standard deviation of 1.7. This radon progeny concentration correlates with a radon concentration of 1400 pCi/m^3 if the equilibrium factor is 50% as assumed in the GEIS. It can be assumed that a geometric standard deviation (GSD) as low as 1.7 would only occur within a single community containing many houses of similar construction and subjected to equal meteorological conditions. On a regional basis, the GSD would be expected to be larger than 2, but possibly not as large as 3.

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(13) Natural Background Radiation in the United States, National Council on Radiation Protection and Measurements, NCRP Report No. 45, 1975.

(14) Peterson, B. H., Background Working Levels and the Remedial Action Guidelines, presented at the Radon Workshop, Health and Safety Laboratory, New York City, February 1977 (HASL-325, 1977).

If one assumes a geometric mean concentration of 900 pCi/m^3 for the western region and a geometric standard deviation of 2.2, the resultant distribution would indicate that 15% of the homes in the region would have average indoor concentrations greater than 1980 pCi/m^3, 2.3% would have concentrations exceeding 4400 pCi/m^3, and 0.13% would have concentrations exceeding 9600 pCi/m^3. The latter would be equivalent to a radon progeny concentration at 50% equilibrium of 0.05 WL.

Although there has been no extensive survey of indoor radon and radon progeny concentrations in the United States, extensive surveys conducted in other countries(15-17) indicate concentration

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(15) Steinhausler, et al. Local and Temporal Distribution Pattern of Radon and Daughters in an Urban Environment and Determination of Organ Dose Frequency Distribution with Demoscopical Methods, in the Natural Radiation Environment III Symposium, Houston, TX, April 1978. (Reported on 4600 measurements of indoor radon concentrations in Salzburg, Austria. They observed an arithmetic mean value of 410 pCi/m^3 with a range from less than 50 to 5160 pCi/m^3. Over 6% of the measurements exceeded 2000 pCi/m^3 or approximately 4 times the mean value. The skewed distribution of the data appear to reflect a lognormal distribution, although they were not analyzed in that manner.)

(16) Swedjemark, G. A., Radon in Swedish Dwellings, ibid. (Concentrations in seven types of structures ranged from less than 700 to 15,900 pCi/m^3. For the seven structural types, the average concentrations ranged from 1500 to 11,100 pCi/m^3.)

(17) Cliff, K. D., Measurements for Radon-222 Concentrations in Dwellings in Great Britain, ibid. (Contributions from structural materials to indoor radon inventories in England and Scotland indicated a lognormal distribution with a geometric standard deviation of 3.1. Although the indoor radon or radon progeny concentrations were not reported, the study does indicate the validity of the lognormal distribution and provides evidence of the expected wide range of concentrations.)

distributions comparable to the hypothetical distribution proposed above. Indoor radon concentrations up to 15,900 pCi/m^3 and geometric standard deviations up to 3.1 were reported.

Because of averaging factors, outdoor radon concentrations normally exhibit less variability than indoor concentrations. However, it is expected that radon flux from the ground surface would exhibit a highly variable log-normal distribution owing to the inhomogeneity of radium bearing minerals and soil conditions. Since the radon flux from land surfaces is expected to exhibit at least as much variability as that from building materials(17), a geometric standard deviation of at least 3.0 can be reasonably assumed. The predictable distribution would include:

greater than 1.5 pCi/m^2-sec from 15% of all land area
" " 4.5 " " " 2.3% " " " "
" " 13. " " " 0.13% " " " "
" " 40. " " " 0.003% " " " "

Consequently, it is estimated that a total area at least 3 times greater than that expected to be occupied by all tailings piles in the U. S.(18) exhibits a natural radon flux of at least 40 pCi/m^2-sec.

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(18) 82 currently active or projected new mills (GEIS estimate), plus 22 currently inactive tailings piles, each covering an estimated 250 acres, is equivalent in total area to approximately 0.0013% of the area of the 48 contiguous states.

Within the objective of assuring that radon emissions from tailings piles are within the normal range of natural background for areas of comparable size within the United States, radon emission control to a level of 25 to 30 pCi/m^2-sec would appear reasonable.

The calculations of radiation doses to individuals and populations are presented in the GEIS only to justify the arbitrarily selected emission limit by showing that all resulting doses are truly negligible(19, 20). Even for the very unlikely worst case situation of a residence built directly on a reclaimed tailings pile(20) with a radon emission rate at least 10 times larger than the proposed limit, the indoor exposure rate would still fall within the range of natural background.

The minimum thickness of 3 meters of cover material proposed in the GEIS (pages 17 and 12-19) cannot be justified on the basis of reducing the risk of lung cancer. Furthermore, the amount of cover material required for reducing radon emissions to any extent is overestimated in the GEIS. The calculations (Chapter 11

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(19) With no cover material (flux = 450 pCi/m^2-sec), the annual lung dose commitment to the population of the model region would not exceed 1% of the dose from naturally occurring radon. Reducing the average emission rate to a few pCi/m^2-sec is assumed to limit the contribution from mill tailings to about 0.001% of the population dose from natural radon (p. 9-27).

(20) The annual average indoor exposure to residents of a home built directly on a reclaimed tailings pile (flux = 2 pCi/m^2-sec) was calculated to be 0.0036 WL (p. 9-27); this implies an average indoor radon concentration of 720 pCi/m^3.

and Appendix P) are based on assumptions that do not agree with empirical measurements made by the U. S. Environmental Protection Agency(21).

Tailings piles need to be covered and stablilized to reduce the risk of long-term wind and water erosion. Any amount of cover material will provide some degree of erosion control depending upon local topography, meterology, etc. However, no specified thickness of cover material can provide complete assurance against erosion or against human intrusion or utilization at some future date. Consequently, the criterion of long-term isolation can be satisfied only on a probabalistic basis.

The draft GEIS does not address the improbability of the use of a reclaimed tailings pile as a residential site, nor does it address actual erosion rates of surface materials at potential tailings locations. It presents only the staff judgement that 3 meters of cover is required to assure long-term isolation, with no analysis in support of this judgement or of the consequences of using other thicknesses of cover. Such a judgement, without supporting evidence or analysis, is totally arbitrary.

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(21) Hans, J. M., et al, Estimated Average Annual Radon-222 Concentrations Around Former Uranium Mill Site in Shiprock, New Mexico. Report No. ORP/LV-78-7, U. S. Environmental Protection Agency, 1978. (Measurements made at a partially reclaimed tailings pile indicated that approximately 3 feet of earth cover reduced the radon emission by a factor of 8. This finding would imply a reduction by a factor of 64 for 6 feet and a factor of 500 for 9 feet, less than 3 meters. The cover used in this case was local soil and included no clay.)

Conclusions:

1. Due to the defects I have described, the draft GEIS cannot serve as a valid basis for proposed regulations.

2. The GEIS should utilize the best available dose-response models and risk estimates for calculating the benefits of radon emission controls. The implications of the relative risk model with regard to carcinogenic co-factors, and in the light of initiator-promoter models of carcinogenesis, should be recognized and utilized.

3. The GEIS should compare the calculated release rates from uranium mill tailings with the natural distribution (range) of radon flux, not simply with the average.

4. The calculations of impacts in the GEIS, and in proposed regulations, should assure that radiation exposures to populations will be within the normal range of natural background exposures.

TESTIMONY OF GORDON T. SWANBY

COST UNDERESTIMATES IN THE DRAFT GEIS

My name is Gordon T. Swanby. I am Vice President of Environmental and Engineering of Atlas Minerals which is a division of Atlas Corporation. Today, however, I am going to discuss on behalf of AMC the approach to costs and the cost data contained in the draft GEIS.

Because of my 25 years experience as a project manager with a major engineering contracting firm I have developed and reviewed many cost estimates. I appreciate the problems encountered by the writers of the draft in attempting to assemble accurate cost figures. I once prepared an estimate on a small project for a client and I informed the client the cost would be $5,500. He was so delighted I decided to check my estimate further and much to my chagrin I found the cost was $55,000. I recently dealt with an estimate for installing a scrubber at a power plant to comply with EPA air pollution regulations. The original estimate was $5.8 million. The final installed cost was well in excess of $25 million. From these and many other experiences I have learned that it is far easier to underestimate costs than to overestimate them.

Underestimating often occurs when a project is not thoroughly engineered and understood down to the smallest details. The basic attitude towards costs and cost data in the draft GEIS has led almost inevitably to serious cost underestimation. The result of this attitude is a lack of detailed engineering. This attitude is reflected in the statement on page 12-6:

> "These costs are still considered to be reasonable given the significant benefit associated with them (elimination of the need for continued active maintenance), and because they represent a very small fraction of the price of product or the cost of producing electricity." (Emphasis added)

Thus the draft GEIS assumes that detailed cost estimating is not warranted. This rationale is invalid. We will demonstrate with examples that the costs of compliance with certain of the proposed licensing criteria are truly significant and will noticeably increase the public's utility bills if finally promulgated in the present form.

With reference to costs of alternative mill tailings management programs the draft GEIS states on page K-11:

> "The staff considers the cost estimates to be adequate for the comparison of alternatives and to support decisions regarding generally applicable regulations."

We concur with the staff that the cost estimates are adequate for the comparison of alternatives for a model mill. However, we have concluded that these estimates are not accurate enough to be used to support regulatory decisions involving real mills.

Let me now turn to some specific cases where the draft GEIS has inaccurately estimated major costs.

Page K-26, Sec. 1.1 discusses the problem of achieving radon attenuation where clay is not available for use as cover material. It states that this 9 million cu. yds. of material can be put into place for $9 million. This $1.00/cu. yd. cost figure is arrived at using $0.75/cu. yd. for excavating, loading and hauling, and $0.25/cu. yd. for spreading and compacting as per Table K-4.1.

Unfortunately, this overlooks the fill required for embankment slopes. This oversight amounts to 4 million cu. yds. based on a minimum slope of 5:1 -- the prudent, conservative measure discussed on page 9-36. Thus the total cover material requirement is 13 million cu. yds rather than 9 million cu. yds. (See attached chart)

The draft GEIS also assumes cover material will be available on site, free of cost. Although we know of no mill site that has 13 million cu. yds. available on the site for excavation, for purposes of discussion, let's assume free dirt on site. If we limit the depth of excavation of this free dirt to 3 ft., we will need to remove 3 ft. of soil from 2,687 acres (or over 4 sq. miles) to obtain 13 million cu. yds. of material.

After this has been done there undoubtedly will be regulatory requirements to resurface and revegetate this borrow area. A recent composite of industry estimates of revegetation costs indicates the cost would be on the order of $5,000 per acre, which in this example results in a total revegetation cost of $13,433,000.

Assuming that scraping up 4 square miles of dirt is not reasonable, another alternative would be to excavate a pit 60 ft. deep to provide the cover soil, but such a pit would require 134 acres plus the side slope areas. This 60 foot hole would be about 2200 feet square. The proposed criteria indicate that such holes should be backfilled and the next question which arises is -- where will this 13 million cu. yds. of fill come from?

Recently I have been deeply involved in trying to determine what costs would be involved in complying with the draft GEIS tailings cover requirement. To date the only nearby clay we have found is on BLM land. We have no idea what this clay might cost but we are certain that the material will not be free.

We have found some dirt that can be delivered for about \$2.00/cu. yd. After assessing all available data we believe the acquisition charge for the 13 million yards discussed above should be estimated at no less that \$3.00/cu. yd. or \$39 million. We don't know at this juncture whether it would be cheaper to rehabilitate the 60 ft. pit or to revegetate the 2,687 acres. But for the moment we will assume they are equally costly (\$13 million).

Thus, the total cost for this entire operation is not \$9 million, as discussed in the draft GEIS, but will require \$39 million for material acquisition, \$13 million for placing and compacting and \$13 million for revegetation or rehabilitation of the borrow pit. The total cost would be \$65 million, over seven times the draft GEIS figure. Even this calculation excludes costs such as interest.

With regard to Item 4, Evaporation Pond, on page K-6, the total cost of \$1.72 million for 40 hectares (or 100 acres) appears reasonable for the work performed. However, this estimate assumes a perfectly level site, free dirt, no pipelines or pumping facilities, no access roads, and no weather protection costs. When this total scope of work is considered, it will probably double this cost.

With regard to site decommissioning, Table K-7.1 states that the buildings and machinery can be removed without cost.

This might be valid for commercial warehouse type buildings but is not a valid assumption in the uranium milling context where the proposed criteria would require that heavy concrete foundations be broken up and hauled to the tailings pond. According to the cost data of one of the leading engineering-contractors, the demolition cost for concrete is $20/cu. yd. Assuming the hauling and disposal cost for this concrete would be $10/cu. yd., then the total cost for this item alone is about $250,000.

Another major engineering-contractor estimates demolition costs to be 6.5% of the capital cost. Thus demolition of a $30,000,000 mill would cost $1,950,000. The draft GEIS quotes, on page K-32, as substantiation for their "No Cost" concept, a letter from a Mr. Gary Beach, of the Wyoming Department of Environmental Quality. We suggest that the operating contractors that actually do demolition work are a much more credible source for estimating information than Mr. Beach.

In summary, it is AMC's position that the draft GEIS assumption of no cost for building and machinery removal is not valid.

Turning to the draft GEIS discussion of the construction cost of a mill. Appendix K-4 sets forth a total cost of $7.1 million for mill equipment. It is not clear whether this figure ($7.1 million) is intended to represent the total cost of a mill. If it is, it is seriously deficient as current engineering estimates for a complete mill with a 2,000 tons per day capacity vary from $25-45 million.

Finally, the draft GEIS does not address the costs of regulation. I have personal knowledge of one company that has spent over $1 million in recent years preparing various reports in an attempt to get a license renewed. Another company has to date, spent in excess of $1 million trying to get an agreement with NRC on a tailings disposal plan. They have estimated on the public record that their total regulatory costs before they finally obtain a license will be $1.5-2 million.

An even more significant regulatory cost is the interest cost imposed by regulatory delays. The largest single cost in constructing a nuclear power plant today is the interest cost during construction or "IDC". This is a larger cost than either labor or materials. All this IDC cost is not necessarily attributable to regulatory delay in every case but in many cases a substantial portion is. One uranium developer has estimated his IDC cost to be over $50,000/day. If we add the IDC cost to the $65,000,000 discussed above, this IDC charge alone would probably be more than the GEIS <u>total</u> cost estimate of $9,000,000. A thorough presentation of costs must include these items.

Earlier in this presentation I alluded to the ultimate cost to the consuming public. If a thorough presentation of costs is made it will undoubtedly show that the 1% increase in the cost of yellow cake assumed in the GEIS will be closer to 3% or more. A recent calculation of the effect of a 3% increase (using the 2.5c/Kwh cost of electricity set out on page 12-4 of the draft GEIS) indicates that utility bills will be increased by at least $100,000,000/year.

In conclusion, the improper approach and the examples of inaccuracies and omissions discussed above, make it clear that the cost estimates contained in the draft GEIS are not sufficiently accurate for use in any meaningful cost-benefit analysis. Therefore, it is our recommendation that the cost data be redone with particular emphasis on the secondary costs that will be involved such as the cost for acquiring dirt, the cost of rehabilitating any borrow areas, and IDC costs.

TESTIMONY OF DR. BERNARD L. COHEN

RADIOLOGICAL RISK IN PERSPECTIVE AND THE MECHANISMS FOR MAKING RATIONAL DECISIONS ON RISK REDUCTION

My name is Bernard L. Cohen. I have worked as a nuclear scientist for over 30 years, and for the past 21 years I have been a professor of Physics at the University of Pittsburgh. From 1965-1978 I was Director of the Scaife Nuclear Laboratories. I was Chairman of the American Physical Society Division of Nuclear Physics in 1974-75, and am currently Chairman-elect of the American Nuclear Society, Division of Environmental Sciences.

The subject I will discuss today is how our society should approach decision making in the radiation health risk area. Risk is an inherent aspect of life itself. In whatever we do, wherever we go, we are constantly exposed to many risks. Indeed, we cannot eliminate these risks, we can only reduce them to some level that each of us individually, or our society collectively, considers acceptable.

The draft GEIS devotes much discussion to the potential risks from radiation from uranium mills. It assumes that there will be 82 model uranium mills each having a 2000-ton per day capacity operating in the United States by the year 2000. Each of these model mills will have a tailings disposal area from which radon gas will be emitted well into the future. Using a modelng analysis, the draft GEIS predicts anticipated adverse health effects on an annual basis from exposure of the general population to emissions of this radon gas from each tailings disposal area at a rate of 450 pCi/m^2-sec. The draft GEIS then calculates economic costs of reducing this exposure by limiting the radon flux rate to 2 pCi/m^2-sec above natural background levels.

To determine whether it is cost effective to impose this degree of radon flux control, a number of factors must be considered. The American Mining Congress will include in its written comments on the draft GEIS a detailed discussion of these factors. I will summarize the major points here.

Radiological Risks Relative To Other Daily Life Risks

The draft GEIS predicts that the long-term health effects to the North American population from radiation from the projected 82 model uranium mills will be less than 10 fatalities per year among the projected maximum 460 million population that will be reached in the next century. Translating this into today's terms for comparison purposes, this is equivalent to 4 fatalities per year in the present U.S. population. Currently, some other risks we all encounter cause the following number of annual fatalities in the U.S. population:

All accidents	100,000
Alcohol	50,000
Automobile accidents	50,000
Suicide	28,000
Homicide	21,000
Drowning	8,000
Illicit drugs	6,000
Poisons	4,000
Choking on food	3,000

Clearly the predicted adverse health effects from uranium milling milling are many orders of magnitude less than many other risks, including some that we do little to reduce any further.

A more striking perspective is gained by translating these uranium mill emissions risks into reduced life expectancy figures. The emissions from all the predicted mills would reduce future life expectancy by about fifteen (15) minutes. Other activities that cause this same life expectancy loss are (1) smoking 1½ cigarettes in a lifetime, (2) driving an extra ½ mile per year, (3) living in a house without a smoke detector for one month, (4) crossing a street one extra time every two years, (5) taking one short airplane flight in a lifetime, or (6) an overweight person eating 100 extra calories (such as one piece of bread and butter or one soft drink) in a lifetime.

Even within the narrow question of health effects of radon, there are much more serious things to worry about. Radon gas, of course, is part of the natural background radiation to which we are all exposed every moment of our lives. The government is urging us to insulate our buildings to save energy, but this traps radon gas inside for longer than normal times, and hence increases our exposure to radon. If all U. S. homes were insulated to government specifications, the increased annual fatality toll from radon would be over a thousand times higher than that caused by mill tailings without covers.

Determination of an Appropriate Period of Integration for Health Effects Averted by Risk Reduction Techniques

At present the usual technique to reduce radon flux from mill tailings is to cover the tailings with some amount and type of material that will retard the radon emanation rate. While the health risk reduction benefits from covering tailings will extend into the future, the bulk of the economic, social, and environmental costs of the covering operations will occur much earlier--that is during the period of mill operation and decommissioning. Therefore, the benefits must be integrated over some reasonable period.

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The draft GEIS seems to have essentially considered selection of an integration period as an intractable problem and part of the justification for not doing a cost effectiveness analysis. The problem may be difficult but it isn't impossible. It is not my purpose here to specify a single appropriate time period but rather to highlight the considerations that must go into selecting the integration period.

First, over extremely long time periods, erosion will bring essentially all the naturally-occurring uranium close enough to the earth's surface to permit radon emanation. If we integrate over very long periods, there is thus no net harm in mining uranium and creating mill tailings; the total number of health effects will be the same.

Second, an important consideration is the effect of discounting the money that would be available in the future to avert health effects but for its commitment now to complying with regulatory controls. For instance, assuming even a 1% annual real interest rate, for every million dollars spent now, we will forego the availability of $20 billion a thousand years from now to avert health effects.

Third, there are highly unpredictable factors in considering very long time periods. There may well be a cure for cancer, or an antidote for radiation, or it may be determined that low level radiation is harmless.

For all of these reasons, it is generally considered unreasonable to integrate effects beyond a few hundred years. Many prestigious scientific study groups, federal agencies, and international bodies routinely use integration periods in this range.

Selection of a Cost per Health Effect Averted Decision Criterion

Our society frequently makes judgments on how much saving a human life is worth in economic costs. The range of such costs per health effect averted provides the best background from which to make a judgment on such cost criterion. AMC's written comments will include a full presentation of these costs. I will only summarize the features here briefly.

In the area of medical screening and care, many fatalities could be averted at costs ranging from $10,000 to $200,000. Additional safety equipment is usually not included in automobiles when costs per life saved exceed about $200,000. Many lives could be saved in safety-oriented highway design improvements for costs ranging from $20,000 to $280,000 with several items in the $40,000 range.

These figures would suggest that if the cost per health effect averted by reducing radon flux from uranium mill tailings exceeds a figure in the range of the items just discussed, then it will be more cost effective to use our society's limited financial resources to save lives in these other areas rather than to commit these funds to radon flux control measures.

To demonstrate that a rigorous cost effectiveness analysis is indeed possible in this area, AMC has analyzed, on a preliminary basis and in draft GEIS terms using draft GEIS data, the cost per health effect averted of one of the proposed criteria -- criterion 6 dealing with reducing radon flux from uranium mill tailings. Dr. Harrison B. Rhodes of Union Carbide Corporation will now discuss the results of AMC's preliminary analysis.

TESTIMONY OF DR. HARRISON B. RHODES

On behalf of the American Mining Congress
at the Nuclear Regulatory Commission's Hearings
on the Draft Generic Environmetal Impact Statement
(Draft GEIS) on Uranium Milling
and on the
Associated Proposed Regulation Changes

My name is Harrison B. Rhodes. I am employed by the Union Carbide Corporation as a Technology Manager in the Safety, Health and Environmental Affairs Department of the Metals Division. My educational background is in Chemical Engineering where I hold a Doctor of Engineering Science degree from Columbia University.

In the draft GEIS, after pointing out certain problems involved, the NRC staff concludes that a rigorous cost-benefit analysis cannot be made. In its place an arbitrary . . . "simple objective of . . . returning disposal sites to conditions which are reasonably near those of the surrounding environment" is selected as the basis for control.

The AMC believes that at a minimum a rigorous cost effectiveness analysis of each subject for potential regulatory control can and must be included in the GEIS. In the final analysis, society, through its electric bills, will pay for the risk control measures mandated by the NRC. Society has the right to know its money is being spent in a prudent and effective manner on solutions to problems that are truly significant to public health and well-being. It is in everyone's best interest to make the best decision possible. This discussion is presented in the spirit of developing a fully informed decision.

There is no cost effectiveness analysis in the draft GEIS. To demonstrate that such an analysis is indeed possible, AMC has prepared an analysis of one of the subject areas of the proposed licensing criteria -- the subject of tailings cover to reduce radon emanation to 2 pCi/m^2-sec above natural background radiation levels. Naturally the basic rationale for any tailings cover is to reduce persistent health effects to levels acceptable to society.

Risk from Various Levels of Radon Flux Control

Table 12.5, page 12-18, of the draft GEIS presents a series of cumulative health effects based on the persistent total continental environmental dose commitments given in Table 6.39. The same calculation technique has been used by AMC to expand Table 12.5 to give a complete picture of regional, far-field and continental effects. Both cumulative and incremental health effects for each successive reduction in radon flux have been calculated for all levels of control and the near-field and continental populations of 517,000 and 460 million, respectively have been used to express the cumulative risks as a rate in terms of deaths/million/year.

It is repeatedly stated in the draft GEIS that every effort was made to present a "worst case" analysis. As discussed earlier in our testimony today and in Denver, this approach has been taken to such an extreme in the draft GEIS that the risks have been seriously overestimated and the costs similarly underestimated. In addition to using the draft GEIS data, we have done a cost effectiveness analysis of the tailing cover issue based on more realistic, yet still properly conservative, risks and costs predictions.

Comparison of Risks

Annual rates of risk for the regional, far-field and continental populations based on the draft GEIS values are shown as a function of radon flux in Figure 1. Regional values based on a more realistic risk estimate are also given. A variety of occupational and general public risks are also shown. Note that these other risks are not related to any particular radon flux and are presented in an orderly fashion in the open portion of the figure.

It should also be noted that the wide range of risks to be included made it necessary to use a logarithmatic scale on the vertical axis. Therefore, each major division represents an order of magnitude so that each is ten times the next lower division.

Consider first the risks taken directly from the draft GEIS. The far-field and continental risks shown in the bottom two curves are lower than those for the regional population by factors of about 200 and 250, respectively. On a far-field basis the risk from uncovered tailings is nearly an order of magnitude below the lower end of a suggested acceptable risk range of 0.1 to 1 health effects per million persons per year, and is about the same as an FDA recommendation of an acceptable level of risk for carcinogenic residues in meat products.

The draft GEIS risks are shown by the upper curve in the figure. At the base case level of no control (a flux of 450 pCi/m^2-sec) the risk is about 4. This is about 1/20 of the risk of natural background radiation, about 1/3 the risk of being in a room with a smoker or the risk from common household accidents. The 2 pCi/m^2-sec requirement suggested by the GEIS is clearly not supported by the risks.

Consider next the regional risks based on more realistic estimates. The risk from uncovered tailings is at the low end of the suggested acceptable risk range. At a flux of 25 pCi/m^2-sec the risk matches the FDA suggestion for food residues. The 2 pCi/m^2-sec proposed flux level presents only 1/100 of this risk.

The comparison of the absolute risks from uranium milling to other risks found acceptable to society demonstrates that the resources proposed to be committed to cover uranium mill tailings could be more effectively used to reduce other risks.

We recognize that health effects to both the average person and to those who live nearer to a source should be considered. Based on the draft GEIS values a maximum flux in the range of 10-100 pCi/m^2-sec brings the risk within an acceptable range *vis-a-vis* other risks in society. Using realistic but still conservative risk projections an acceptable risk factor is reached at 100 pCi/m^2-sec. The 2 pCi/m^2-sec level is far below the acceptable risk range.

Cost Effectiveness of Various Levels of Radon Flux Control

The draft GEIS analysis cannot be used as a basis for decision making because only average rather than incremental costs and health effects are discussed. The use of average costs is misleading because the cost of cover is directly proportional to the depth used while the corresponding health benefits decrease in an exponential manner for each additional increment of cover material. In other words, the first foot added is more effective than the second and so on. In this situation the critical variable is not the overall average cost per health effect averted but what does an incremental additional expenditure provide in terms of the incremental number of health effects averted. In our analysis we have used the draft GEIS data to derive these incremental figures for each of the types of cover material discussed in the draft GEIS. Similar calculations were made using more realistic cost and risk predictions.

The inter-relationships of cost per health effect averted, total depth of cover material, and radon flux rates is shown in Figure 2. The ordinate is the incremental cost per health effect averted (log scale) and the abscissa is the total depth of cover in meters. A solid line is given for each of the three types of cover based on the draft GEIS values with the numbers by each point showing the corresponding flux limit in pCi/m^2-sec. A suggested range of appropriate societal cost per health effect averted of \$250,000-\$500,000 is also shown for reference.

Using these values from the GEIS it is evident from Figure 2 that the radon flux level that can be attained in the suggested range of societal costs is strongly dependent on the type of cover available. For the clay plus Soil A a range of 4-7 pCi/m^2-sec occurs at a total cover of about 1-1/4 meters; for Soil A alone the range is 40-60 pCi/m^2-sec at a depth of 1-1/2 - 2 meters; and for Soil B only 60-100 pCi/m^2-sec can be reached at a cover depth of 2-3 meters. To reach the level of 2 pCi/m^2-sec recommended by the staff, costs would range from 8 to 24 million dollars per health effect averted, at depths of 2, 4, and 8 meters, respectively (Clay + A, A, B). Even a 1000 year integration period would only reduce the range to 800 thousand to 2.4 million dollars per health effect averted.

Figure 3 presents values based on more realistic (but still conservative) risk and cost projections developed on a preliminary basis by AMC. Because the number of potential health effects are considerably lower than the draft GEIS values and the costs are at least double the draft GEIS values, the cost per health effect averted curves shifts upward sharply from those shown in the previous graph. All of the results are an order of magnitude or more above the suggested range of appropriate societal costs. The 2 pCi/m^2-sec. control level is off the graph -- i.e., above $100,000,000 per health effect averted -- for <u>all</u> of the soil types studied.

Conclusion

The GEIS estimates shown in Figure 2 demonstrate and the AMC estimates in Figure 3 emphasize that large expenditures of societal resources to reduce radon flux from tailings piles to very low levels is neither cost effective nor reasonable. There are many more effective ways to reduce societal risks. These results also show that the inflexible level of 2 pCi/m^2-sec. specified in the proposed licensing criteria is unreasonable. It is also clear that site specific considerations, such as the cover material available at a reasonable cost, must strongly influence the acceptable radon flux rate.

RISK COMPARISON

REGIONAL AND CONTINENTAL EXPOSURES

OCCUPATIONAL AND DAILY LIVING

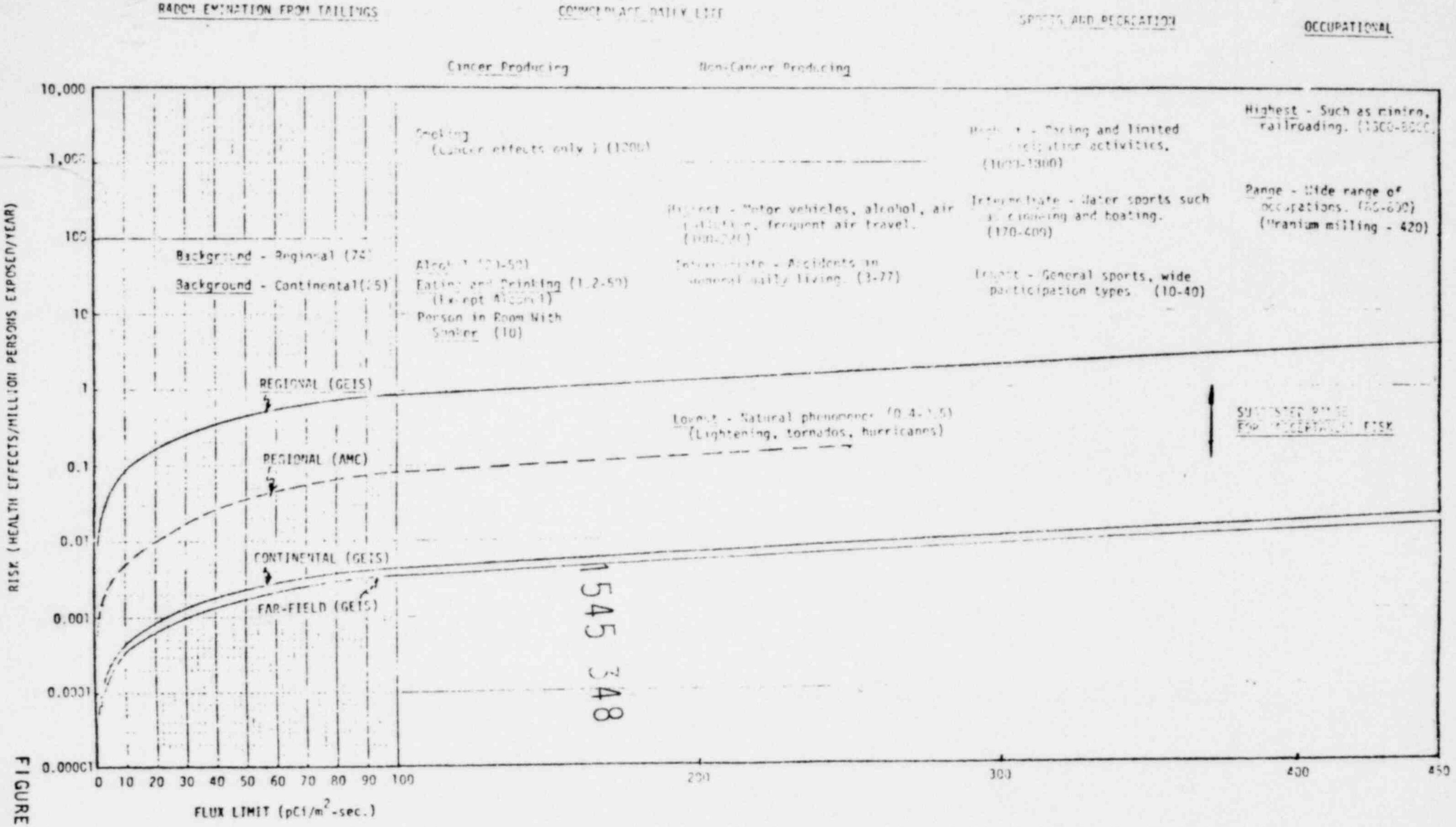

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FIGURE 1

FIGURE 2

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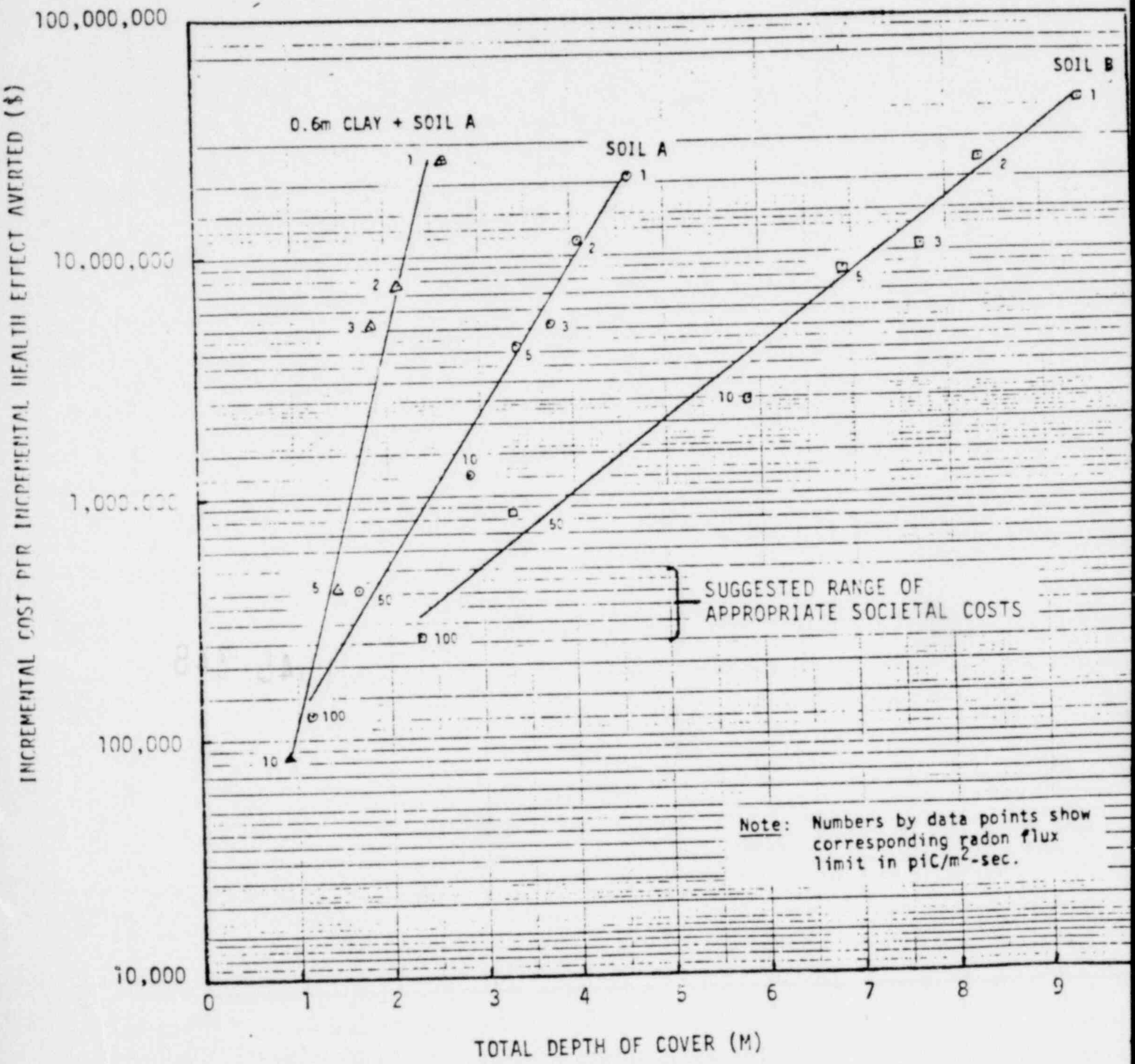
GEIS ESTIMATE OF INCREMENTAL COSTS PER INCREMENTAL HEALTH EFFECT AVERTED

Continental Effects

100 Year Integration

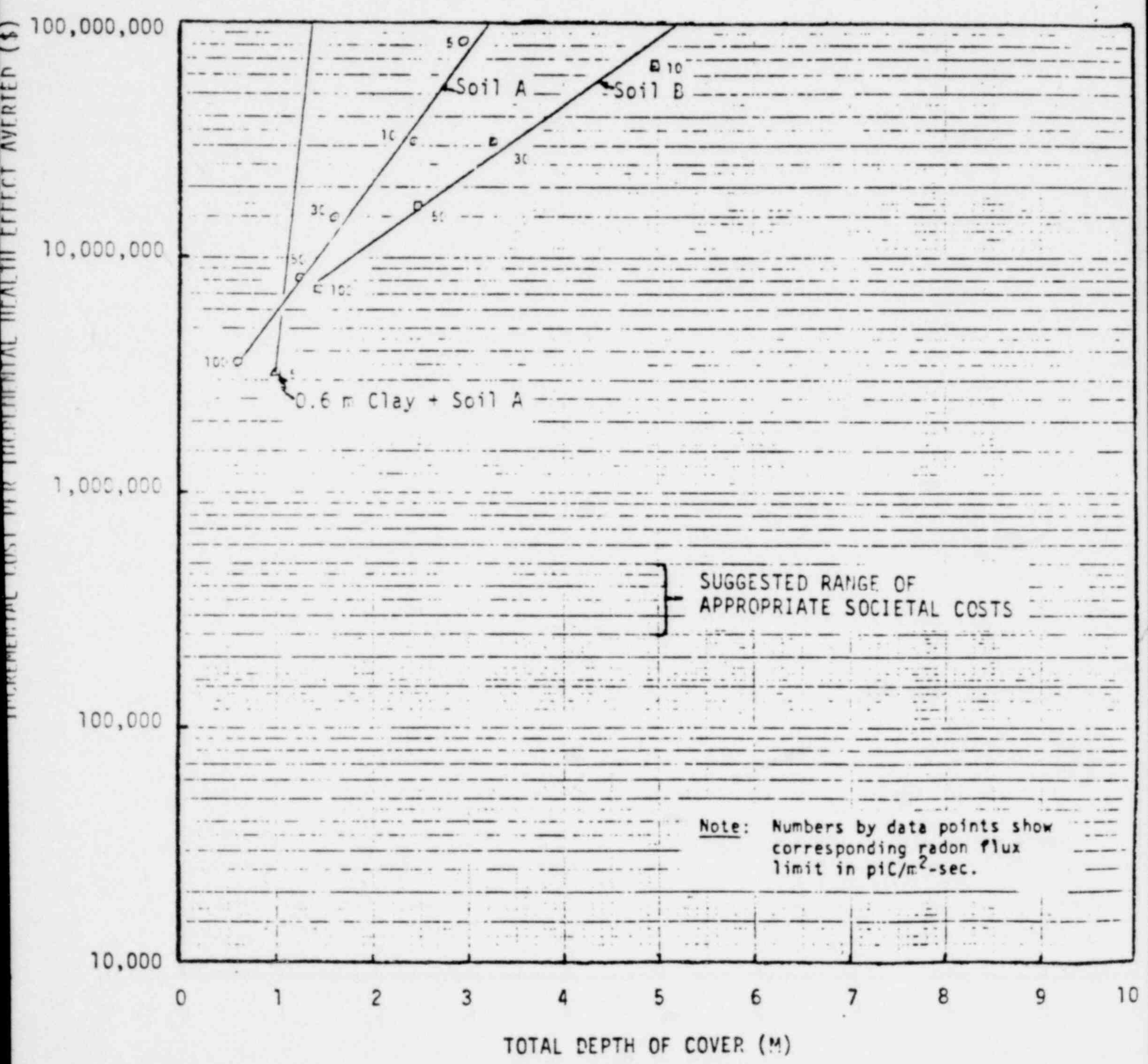


Note: Numbers by data points show corresponding radon flux limit in piC/m^2-sec.

FIGURE 3

AMC ESTIMATE OF INCREMENTAL COST PER INCREMENTAL HEALTH EFFECT AVERTED

Continental Effects 100 Year Integration



Note: Numbers by data points show corresponding radon flux limit in piC/m^2-sec.

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CLOSING STATEMENT - LANGAN SWENT

Mr. Chairman, I wish to express our thanks and appreciation for the opportunity to present this oral summary of our views. We in the American Mining Congress hope that our comments will be received in the spirit in which they are offered -- that is, to help in the development of reasonable, effective regulations for uranium milling operations which will assure adequate protection for public health and safety and the environment without unduly penalizing the uranium milling industry with unnecessary requirements for which, in the long run, the public must pay.

We think you should be cognizant that in making decisions on how much to reduce various risks, we all, consciously or unconsciously, weigh the costs of achieving the risk reduction benefit we seek. On an individual basis, this decision -- how much reduction in risk is reasonable in light of the costs -- is a very personal matter. When judgments are made by and for our whole society on risk reduction, the elements that go into the decision and the means by which each element figures in the balance should be well explained to and understood by the public. Without this frame of reference, rational decisions cannot be made.

Mr. Chairman, this concludes the AMC presentation.

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