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M-25

ENVIRONMENTAL COALITION ON NUCLEAR POWER

Co-Directors: Mr. George Boomsma—R.D. #1, Peach Bottom, Pa. 17563 717-548-2836
Dr. Judith Johnsrud—433 Orlando Avenue, State College, Pa. 16801 814-237-3900

24 October 1979

Director
Division of Waste Management
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Madame or Sir:

Enclosed are my comments on NUREG-0511. These comments are voluminous, but this is an unfortunate necessity because of the large number of misinterpretations and misstatements of fact contained in the Draft Report and the glaring omissions from the Draft Report.

I trust these comments, with the three attachments, will be reproduced in their entirety in the Final Report. Full reproduction of comments in the Final Report, with the associated response, is a much more satisfactory approach than to reproduce selected portions of certain comments but only after those comments have been smoothed and averaged and sanitized by the NRC Staff and homogenized with the associated responses of the Staff. I trust that the former procedure will be utilized for the Final GEIS Report.

Sincerely,

Chauncey Kepford

Chauncey Kepford
Legal Representative
Environmental Coalition
on Nuclear Power

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Introduction

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In the Draft Statement on Milling, the NRC grossly underestimates radiation exposure information by creating the impression that the exposure of the public from uranium milling activities and its aftermath causes only minimal health problems. This conclusion of the Draft GEIS is reached only by extreme manipulations and distortions of data and information. It is truly unfortunate that the NRC Staff, which is charged by law with the protection of the health and safety of the public, consciously has chosen to ignore its statutory obligations so as to promote nuclear power, the dirtiest and most insidious of all sources of electricity, one for which the benefits are unnecessary and the costs in terms of additional human deaths and additional human misery will go on for as long as there are humans on earth.

The primary focus of these comments will be upon the radiological aspects of this Draft Statement. Since the details of the radiological discussions in the Draft are contained mostly in Appendices C and G, these comments are directed primarily, though not exclusively, at these Appendices.

Main Report-Summary

1. Having read the appendices to this report first, I am appalled at the Summary. It seems that nothing at all has been learned from the unfortunate experiences with WASH-1400, called the Rasmussen Report. As many numbers which appear in the Summary tables get condensed from the text and Appendices, a strange thing happens: the confidence limits, or uncertainty limits, gradually disappear. This is a process which I call Rasmussenization. This process is particularly evident in the discussion of health effects, a euphemism for premature death. Here uncertainty bands which may amount to a factor of 100 or more have been completely discarded. Worse yet, as described in my comments on Appendix G, the Report seriously underestimates the numbers of premature deaths. By this gross underestimation of the cancer (and other) deaths produced by the front end of the fuel cycle the NRC apparently hopes to make its seriously inadequate, stop-gap remedial measures seem acceptable. It is very disturbing to see the successor agency to the AEC, which itself showed utter disdain for uranium mill tailings, following in the same footsteps, repeating the mistakes of past years, only on a more massive scale, using the force of government to ensure that only minimal and inconsequential precautions are taken to prevent future premature deaths from the mill tailings piles.

2. In the Washington Post, October 18, 1979, page A 13, a short article appeared about Durango, Colorado, "site of a large pile of uranium mill tailings." It is reported that "one of two hospitals in the city of 10,000, showed 237 cases of lung cancer diagnosed in the last 15 years. . . . a city the size of Durango would be expected to have 60 cases of lung cancer during that period, based on the national average." Of course, a rash of denials will undoubtedly issue from the NRC, pointing to the altitude, racial makeup, smoking habits, sleeping habits, eating habits, or whatever, to explain away those 177 extra cancer deaths. One hundred and seventy-seven cancer deaths in 15 years is about 12 cancers per year. Some idea of the magnitude of the underestimation in the Draft can be seen by comparing this cancer rate to Table 6.16, which lists the health effects (deaths) for the entire 15 year operating life of a model mill. Here the "premature deaths" are 0.17, or 0.011 per year. Now, these two situations are not strictly comparable. The model mill

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(Table 6.16) is conveniently placed by the NRC Staff in a sparsely populated area so as to artificially reduce the population at risk. On the other hand, mill emissions during active operation are much higher than those from abandoned mill tailings piles, such as the one at Durango, so the two factors tend to compensate for each other. This unfortunate situation in the real world today must now be compared with the unconscionably feeble consolation offered to future generations by the NRC Staff (page 20).

> If degradation or failure of isolation of mill tailings were to occur, it would not lead to catastrophic radiation effects. There would be ample time to take corrective action.

It should here be observed that isolation has never taken place in Durango, and that the pile was only partially stabilised, only somewhat reducing radon emissions. (See Table 2.1.) The NRC should explain exactly how many lives must be lost before the real magnitude of the problem is recognized and "corrective action" will be taken, using the present day practices of the NRC itself as an example.

3. The entire draft should be rewritten to reflect the real ranges and uncertainties in cancer, other premature death and genetic risk estimators, radionuclide transfer coefficients, and dose conversion factors so the reader can see for him- or herself the full, unadulterated range of health effects, both short and long term (long term in the meaning of the full applicable period of toxicity), from uranium milling. The final GEIS can not be confined to just those few health effects which the NRC wants to reveal. The final GEIS must include all health effects for the full period of toxicity.

4. The discussion of disposal modes is incomplete and misleading. At the bottom of the page, reference is made to "failure" events. A discussion should also be added examining the consequences of both short and long term (full period of toxicity) regulatory failures, as they have occurred in the past, and, if the Durango lung cancer epidemic mentioned above is any example, are probably still occurring.

5. Table 4 lists costs of alternative disposal modes and the costs as a percentage of uranium produced, assuming a price of \$30 per pound of U_3O_8. Since the market price is much higher than \$30 a pound and is likely to appreciate substantially in future years, there seems little justification for this figure, other than to make the costs of proper disposal (that is, permanent disposal) of mill tailings piles appear more expensive by comparison.

6. Table 4 does not appear to contain the sums required for surveillance and monitoring for however long these are to be carried out.

7. The comparison of mill tailings with actinides on page 16 suffers from a certain amount of myopia. Prior to the very recent report from Durango, have there not been several reports of abnormal birth defects in certain counties in Colorado which contain mill tailings piles? Prior to the issuance of the final GEIS, the NRC should check the lung cancer incidence in the <u>other</u> hospital in Durango, and the lung cancer incidence in Grand Junction, and all other towns adjacent to a mill tailings pile, including the town of Edgemont, S.D., where a pile which does not yet appear even to be acknowledged in fact exists. (I know that it exists, having seen it as recently as July, 1979.)

8. The conclusion that deep burial is impractical (page 16) does not appear to be supported by any real evidence. Cost estimates and comparisons should be provided if this kind of statement is to be made. In addition, some discussion should be included concerning the effects of deep disposal on radon releases over the toxic period of the wastes, as in the comparison in Appendix L.

9. The reluctance of the NRC Staff to monetize the benefits (if there are any) and costs of the mill tailings portion of the nuclear fuel cycle is understandable but unacceptable. To do a full cost analysis would require a full, open, candid treatment of the temporal magnitude of this radon emissions problem which is due solely to the intervention of man. Instead, the Draft resorts to denying the existence of the problem, assuming that future lives are worth less than present day lives (The Durango experience offers the hope for a future society which will value human life more than we do.), or invoking glaciers or some other purely speculative or even imaginary reason to ignore the problem. The first principle of radiation protection is that there should be no exposure without the expectation of a commensurate benefit. (BEIR Report, p. 2). It seems that the NRC is willing to turn its back on this fundamental principle in order to make things easier for an already floundering industry. Reason and rationality would suggest a strong correlation between the potential duration of the problem and the longevity of any proposed solutions to the problem.

10. If the "conservatism in siting and design" policies of the Staff (page [illegible]) represent the same degree of conservatism shown in Appendix G, then future generations will pay an enormous tax to this generation's profligate use of nuclear-generated electricity in the form of sickness and premature deaths resultant from radioactivity attributable to the fuel cycle for today's reactors. Assertions of conservatism are mere rhetoric and hand-waving unless there is substantial experimental evidence to support such statements. And if the enforcement arm of the NRC will be as stern and strict with mill tailings problems as it has been and is with chronic, repeated, and serious safety violations at nuclear power plants, then the uranium millers already know the NRC will cover for them and protect them from the public no matter what the cost to human health and lives, in just the same way as the NRC is now clearing the way for a restart of TMI-1, adjacent to the crippled TMI-2

11. The offer of "public participation" in the mill licensing process will undoubtedly prove to be as much of a hoax, charade, and fraud as is the reactor licensing process. There, of course, <u>every</u> commercial reactor license requested has been granted, regardless of the incompetence of management, inadequacies of design, construction, and operation. In fact, the TMI-2 experience offers a good look at the way the licensing system works, and the lengths to which the NRC will go both to thwart and stymie effective public participation and to protect the nuclear industry. The TMI-2 licensing proceeding in 1977 was the first in which the full magnitude of the radon emissions and projected health effects were raised for inclusion in the cost-benefit analysis. That issue, and one other involving the probability of a Class 9 accident, remain unresolved as of this writing, but in the "sentence first, verdict later" tradition typical of NRC licensing proceedings, the TMI-2 reactor was licensed to operate anyway, was rushed into service so that the owners could capitalize on tax breaks in spite of a rash of mechanical difficulties, and, on March 28, 1979, began the nation's worst reactor accident, which is still in progress. However, the story of the real NRC licensing scheme does not end there. In April and May of 1979, the participants in the original TMI-2 licensing proceeding, shocked by the accident, petitioned the NRC requesting, among other things, a) to be informed of any construction at TMI-2 or modification of TMI-2 or modifications of its operating license, and b) that public hearings be held prior to any alterations of TMI-2 or changes in the operating license or its technical specifications. The result of those requests in April and May, 1979, was that the NRC cut off those original (and still fully participating) TMI-2 Intervenors from any further information on TMI-2 of any kind, including all information about the construction activities for Epicor-II (the system designed to partially decontaminate some of the lesser contaminated water at TMI-2), and failed to provide these Intervenors with even a copy of the "Environmental Assessment" of Epicor-II and proposed changes in the operating license

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specifications. Some six months later, but only after Epicor-II was built, and only after the Commissioners themselves had already approved and ordered immediate operation of Epicor-II, the NRC offered persons whose interests might be affected a 20-day period to petition the NRC for a public hearing, while the Epicor-II system was being allowed to operate! This is the "public participation" of the NRC in action. It is truly "sentence first, verdict later," with no effort spared to cover up for the company that perpetrated the accident and to protect that company from the public whom the NRC is mandated to protect.

12. Table 6, like Table 6.16 and Appendix G, must be rewritten to reflect the full range of open literature values which go into each number. In addition, some attention should be paid to the real world, such a the Durango excess of lung cancers. It seems incredible that the NRC Staff estimates that fewer cancers will occur in a 10?? year period from all uranium milling through the year 2000 in the entire United States than have already been observed in a single town of 10,000 in 15 years from one partially stabilized mill tailings pile.

13. Footnote (g) of Table 6 contains a statement with no factual basis whatsoever: viz., the last sentence. Since the dose conversion factor range for radon daughters mentioned in the BEIR Report goes from 0.1 to 20 rads per WLM (Working Level Month), there is a range of variation of 200, not 4 as stated.

14. One subject missing from this Draft is a candid discussion of what the effect would be on the future uranium milling industry of a set of regulations which might be sufficiently stringent to protect the public health and safety, including a strict regulatory atmosphere where license suspensions of a few years duration might actually result for serious infractions by licensees. Since the mill tailings undoubtedly can be disposed of safely (by deep disposal, as is proposed for high level waste) and permanently, it seems apparent that the NRC Staff has decided, either consciously or unconsciously, to condemn to premature death some current lives and an unknown but potentially enormous number of future lives, for the purpose of continuing to allow the uranium milling industry to operate in the manner to which it is accustomed.

This tradeoff is facilitated by the gross underestimation of the health consequences of radon daughter inhalation; by the proposed establishment of what superficially might appear to be strict regulations, but which in reality is only a set of very loose performance criteria or objectives with no real capability or intention of being enforced or even implemented; and by the deliberate avoidance of any substantive and objective discussion of the potential for enormous numbers of premature deaths and genetic disorders far off into the future. These matters are, of course, at the heart of the whole issue, and they cannot be dismissed or treated lightly.

Questions which remain unaddressed include:

(a) What would be the effect on uranium mining and milling and on the public health and safety of requiring the deep disposal of all mill tailings, at a depth of approximately 2000 feet below the surface in bedded salt deposits?

(b) What would be the effect on the industry and the public health and safety of requiring tailings disposal according to Alternative 6, i.e., fixing the tailings in concrete (5 parts tailings to 1 part cement)?

(c) What would be the effect on the industry and the public health and safety of suspending the license of the United Nuclear mill near Churchrock, N.M., for five years, for example, as a result of the licensee's inability or unwillingness to prevent the tailings pond dam failure which recently caused contamination of an important water supply?

(d) What would be the effect of including a monetized value of health effects for the full period of toxicity (using, for example, the methodology of Kepford in the TMI-2 or Perkins 1, 2, and 3 reactor license proceedings) to assess the adequacy of alternative tailings disposal options?

(e) To what extent is the NRC currently in the process of using its power as a governmental regulatory agency to ensure that the mining and milling of uranium proceeds relatively unhindered? Here, a comparison is in order between the efforts of the AEC to encourage uranium production during the 1950's through the mechanism (among many others) of offering mining companies freedom from restrictive mine air quality standards and the current NRC efforts at under-estimation of health effects and neglect of long-term health costs. The full and accurate estimation of long-term health effects and their costs should be undertaken if the GEIS is to serve the purpose of fully informing the public, as NEPA intended.

(f) Should not the American people be given the full details of this pending health tradeoff, with subterfuge, so that they can make an informed decision based on the complete analysis of costs and benefits, rather than a decision based on one-sided allegations of need for more electricity accompanied by omission of the full health consequences?

Chapter 2 - History

1. The truncated view of the uranium milling industry discussed in this chapter mentions uranium mining and the early program of the AEC to offer a wide variety of encouragements to uranium mining companies and millers. However, this history fails to mention the more unpleasant, and totally avoidable, experience involving the conscious, willful exposure of thousands of uranium miners to high levels of radon and radon daughters in improperly ventilated underground mines. Miners' lives were traded, in effect, for higher profit margins (another bonus for mining companies). This exposure occurred in spite of the fact that, even as mining commenced, radon had already been unmistakably identified as a potent carcinogen. A discussion of this subject would add a much needed perspective to this entire chapter. The chapter also is lacking in that it fails to indicate that the AEC's and NRC's attempts to conceal the magnitude of the long-term emissions of radon from the mill tailings piles continue unabated to this very day, and may be expected to do so in the absence of appropriate corrective action.

Chapter 3

1. The definitions of the kinds of ore reserve categories on pages 3-4 are rather vague, especially in the case of "Potential Resources." It appears as though those reserves in categories 2(b) and 2(c) are based almost entirely on hopes and faith. Can any probability be attached as to the likelihood that such quantities of these reserves actually do exist in the dollar category listed in Table 3-6, or are the Staff's estimates based exclusively upon unsupportable conjecture?

2. Footnote c of Table 3.6 quotes a value of 2,425,000 tons of ore reserves as used for planning purposes. How was this figure derived? The Draft also asserts that this figure represents a "conservative" value. Some discussion of how this value is conservative would be most interesting and very helpful.

3. Figure 3.2 shows data only from 1978 on to the year 2000. It does not include data for previous years for those aspects of the industry which are shown in this Figure. In addition, it does not show the uranium requirements of the 380 GW(e) of generating capacity which the Staff indicates is to be expected after the year 2000. As a result, this graph only shows a small portion of the total picture with respect to uranium requirements. We suggest that a second graph be included in the Final GEIS reflecting all available data for the years from, say, 1960 through 2030, including the data which the Staff has already provided.

Chapter 6

1. On page 6-40, the NRC excuses away what it considers one improbable death by concluding that, should the death occur, its cause would be unrecognizable. This reasoning would justify murder by anyone clever enough to leave no detectable traces on the corpse. Tradition has led Western man to regard a crime, such as murder, as being associated with the act of committing the crime. Whether or not the source of the crime is readily detectable is unimportant and irrelevant.

Appendix C

1. The NRC Staff is guilty of a serious misrepresentation on page 2, the third and fourth full paragraphs, of this Appendix, with regard to emissions from the mill tailings piles. The primary radiation exposure occurs due to alpha particles, a form of high-LET radiation. By contrast, the statements contained in those two paragraphs apply to high-LET radiations. As stated in NCRP 43, (1975) pages 11, 12,

> ...the relative biological effectiveness (RBE) of the high-LET radiation must increase as the dose decreases. This has been known for many years. . . .

Similarly, as stated in the BEIR report (Appendix C, ref. 2, page 88)

> Hence, the RBE of high-LET radiations can be expected to increase with decrease in the dose and dose rate.

Nowhere in the Draft are these important concepts enunciated. Instead, as in the above referenced paragraphs of the Draft, the opposite is suggested. Also, the possible numerical increases in the RBE as a function of dose and dose rate must be discussed throughout the final report in relation to all of the calculated doses due to high-LET radiations.

2. The Draft (page C-4) contains a brief discussion of the "Working Level Month" (WLM) but contains no discussion of the criticisms of the concept of the WLM which have appeared in the literature in relation to the actual dose delivered. This omission is significant because, as the Draft itself observes (PC-4), measured radon concentrations do not reflect the inhalation dose. For example, some discussion of the problem of radon daughter build-up in buildings should be included to indicated the relationships among ambient dust levels, air turnover rates, changes in the WLM, etc., in homes and buildings. The discussion of radon inhalation on pages C-5 and C-6 is in terms of radon concentrations, rather than the somewhat more meaningful term WLM. This section should be recast in terms of WLM and fractions thereof.

Appendix E

1. The three parts of Appendix E are devoted primarily to mathematical models of ground water contamination from mill tailings ponds (page E1), rather than to a discussion of actual field observations. Since uranium mining and milling has occurred in the West for a great many years, it is especially disappointing to find so little discussion of the ground water contamination problems which exist (or do not exist) around active and inactive mills. What studies, if any, have been conducted to assess the problem? If indeed problems have been observed, some indication of the regulatory agency response, if any, on both the state and federal levels, should be included in the final GEIS.

2. In particular, the Draft report concludes (page E-19) that for the life of a mill tailings pond, no radium contamination of ground water is expected. It is by no means clear whether or not this conclusion is supported by experience where uranium milling has taken place. One assumes that a study of the recent dam collapse allowing the release of large quantities of contaminated water will be included in the Final GEIS.

Appendix G-1

1. On page G-13, it is observed that the exhalation of radon from mill tailings piles (all soils) is strongly influenced by the moisture content of the tailings (and soils). Yet when it comes to the discussion of radon exhalation from natural soils in Appendix O, this effect of moisture is omitted from the discussion and the calculations. This inconsistency should be removed.

Appendix G-3

1. Paragraph G-3 of this Appendix contains a brief discussion of the concept of the "environmental dose commitment" (EDC). It is not clear, however, from this discussion, or from the more complete one at the end of Appendix G-6, how this EDC works. Since the EDC is for one year's mill operation, does this represent the total impact of the mill? Does this one year EDC get multiplied by a factor of 15, for the assumed 15 year lifetime of the mill?

The Final report should contain a thorough discussion of how the EDC concept is applied to a chronic radioactive release problem like radon from mill tailings piles.

Appendix G-4

1. This Appendix contains a large number of graphs. However, the time period over which the ground concentrations of uranium, thorium, and radium occur cannot be discerned from these graphs.

2. The relationship of Graphs G-4.7,-4.8, -4.9, -4.10 and -4.11 to the quantities of materials released from the model Mill as described in Table 5.5 is unclear. Do these Graphs and this Table represent the same quantities?

3. There does not appear to be any discussion of either the quantity of radon produced annually by the thorium-230 and radium-226 by these dusts from the mill or the persistence of these emissions. A discussion of these points would be important for completeness.

Appendix G-5

1. In recent years, investigators have developed a few "lung models" to try to calculate dose conversion factors for the lung to the alpha particle emitting radon daughters. None of these models created specifically for radon daughter dosimetry are referred to on page G-41. Instead, reference is made to a "mass averaged lung" model and an ICRP lung model. The text makes no mention as to how either of these models compares to the alpha-particle lung models or how applicable either model is to alpha particle emitting dust particles.

2. In addition, the GEIS should describe the effects upon critical tissues of the lung of each of the isotopes under discussion, e.g., uranium-238 and its relevant daughter products.

3. Tables G-5.1 and -5.2 list inhalation dose conversion factors for certain uranium daughters. Missing from this list are Po^{218} and Po^{214}. (Dose conversion factors for these isotopes are relevent to radon inhalation). Furthermore, although the Tables list doses for exposures to various organs and the whole body, there is no discussion relating doses to these organs (and the whole body) to organ sensitivity to alpha particle exposure. Also missing is an examination of whether or not the organs listed are the most critical organs for the various isotopes, with respect to cancer induction.

4. The first sentence in Sec. 1.2 states that the only path of entry into the body for radon gas is through inhalation. There have, however, been reports that water which can be used for drinking may contain levels up to 10,000 pCi/liter or higher of dissolved radon. Some discussion of this pathway as it pertains to uranium milling ought to be provided, along with dose conversion factors for the alpha-particle emitting radon daughters, and a discussion of the fate of radon and its daughters ingested through drinking water.

5. Sec. 1.2 discusses radon in buildings. Some discussion of air-turnover rates in summer and winter would be helpful, as would a discussion of what constitutes an "adequately ventilated room" and a "normally ventilated dwelling". Would these places be habitable in Casper, Wyoming, or Grand Junction, Colorado, in the dead of winter? Do such buildings presently exist? Are there any plans to require that buildings constructed near mill tailings piles comply with any such specifications?

6. On page G-44, it is stated that the radon concentrations equalize between indoors and outside under normal ventilation conditions, which are undefined. What would be the result for higher and lower ventilation rates? On what data are the Draft report's conclusions on this point based?

7. On this same page, it is stated that the concentrations of radon daughters would be lower than the equalized indoor-outdoor radon concentrations due to decay. This seems physically impossible. How does this occur?

8. A set of values for assumed radon and daughter relative concentrations in dwellings is given on page G-44. These concentration ratios affected by changing a) air turnover rates, b) dust levels, and c) the relative humidity. A discussion of these variables is necessary to understanding radon exposures. A discussion of the range of radon and daughter concentration ratios under the above variable conditions should also be included, along with the effect of these variables on the resulting radon daughter exposure.

9. The statement at the top of page G-45, concerning a supposed "detailed discussion" of radon daughter dosimetry, is simply not true. The discussion provided in the BEIR report (pp 146-9) is brief, fragmentary, and incomplete. We suggest that the Staff examine "Guidance for the Control of Radiation Hazards in Uranium Mining," Report No. 8, Revised, of the Federal Radiation Council (FRC), 1967. Even the FRC, whose sweeping denials of the hazards of radiation exposure led to the FRC's own dissolution, suggested a value of 2.8 rads/WLM. Why does the NRC Staff now retreat from that value?

10. Furthermore, it is not at all clear in the BEIR report just where the value of 0.5 rads/WLM quoted at the top of page G-45 comes from. It appears to be based at least in part on unpublished studies referred to in the BEIR Report. The BEIR Report does mention a range of values in the literature ranging from 0.1 to 20 rads per WLM. However, no rational explanation was provided in the BEIR Report for the choice which it adopted, and which was in turn adopted on page G-45 of the Draft GEIS. It is therefore necessary to present a thorough discussion of (a) radon daughter dosimetry, and (b) why the NRC Staff has chosen a dose conversion factor at the low end of the published literature values.

11. In the context of the above remark, on page G-58 of the Draft report, the following claim is made:

> The approach taken...has been to place conservative bounds on health effects....

Unless "conservatism" is to be equated with overlooking the adverse health effects of standard nuclear industry practices wherever possible, it is difficult indeed to understand how the Staff's selection of a value near the low end of the BEIR Report projections can be described as conservative.

12. Still at the top of page G-45, in conjunction with the discussion of the range of dose conversion factors for radon daughters, the Draft report fails to include the effect of decreasing dose and dose rate on the RBE (or quality factor), mentioned in comments on Appendix C, #1.

13. In the middle of page G-45, it is stated that 50% of the initial radioactivity is lost in food preparation. The reference given is to a computer code. There is no further explanation. Is this an assumption which went into the code or an output based on other input assumptions?

14. Table G-5.5 contains a list of dose-conversion factors for ingestion. Again, the primary reference is just to a computer code. Presumably, the factors are computed in the code, but there is no way of telling from the Draft Report itself. Nor is there any discussion of how the (presumably) calculated dose conversion values in Table G-5.5 compare with any other values reported in the open scientific literature.

<u>Appendix G-7</u>

1. It is most interesting to see, on page G-58, that the NRC is slowly accepting the "relative risk" method of calculating lung cancer fatalities in humans. This approach was suggested ten years ago by Dr. John Gofman and Arthur Tamplin in "The Colorado Plateau: Joachimsthal Revisited?", which appeared in hearings before the Senate Committee on Public Works, November, 1969, "Underground Uses of Nuclear Energy", pp. 351-77. In that document, these authors observed a decrease in the "doubling dose" (that dose required to produce a doubled incidence of cancer) as the total WLM exposure decreased, in keeping with the observations of both the BEIR report and NCRP 43 (see my comments, Appendix C, #1). A discussion of the Gofman-Tamplin approach, or even a reference to this much earlier and more complete treatment, would be useful.

2. If the "relative risk" approach is the more " consistent" approach to deal with human lung cancer, (page G-58), it is then disturbing to see that the Staff arrives at the "central value" of lung cancer risk estimates by averaging the "relative risk" estimators with the less appropriate "absolute risk" estimators. An explanation of the justification for this procedure is necessary in this section of the Staff report.

3. Equally disturbing is the fact that each of the four risk estimators listed in the text on page G-60 has its own limits of uncertainty inherent in it. Yet these are stripped away and forgotten, and the "central value" listed in Table G-7.1 lists only the range of the four listed (including the two less appropriate ones) risk estimators. Again, some explanation of this disappearance of ranges of uncertainty for each of the individual values is necessary.

4. The statement is made that "long latency periods and very low probabilities of occurrence" characterise chronic low level exposures to radiation. This conclusion seems at odds with human data on this subject. Saccomanno, et al. (Cancer, 27 515 (1971)) showed that for uranium miners in lower exposure categories, the more prevalent forms of cancers occurred with considerably shorter "induction-latent" periods than did the same cancers in higher exposure categories. Some elaboration on and justification for the above quoted statement is needed, or it should be dropped.

5. A serious internal inconsistency appears in Table G-7.4. In this Table, assumed values of the latency period for lung cancer are stated to be about 15 years. Also given is the relative risk per WLM of 3% increase in lung cancer deaths per WLM exposure. The 3% increase per WLM corresponds to a "doubling dose of about 33 WLM. This value is consistent with that found in a study of lung cancer among Polish uranium miners (Health Physics 30 433 (1976). However, this doubling dose did not include any allowance for any latency period at all. A typical case study might be as follows: a man begins mining uranium at 52 years of age, works in the mines for 14 years, acquires a cumulative exposure of about 900 WLM, is diagnosed as having lung cancer, and dies the year he quits mining at age 66 (Case #66, Archer, et al., Health Physics 25 351 (1973), Table 5). In the subsequent analysis, this death is combined with others of approximately the same total exposure (840 WLM to 1799 WLM). A standard statistical analysis is performed, and, indeed, excess cancers are observed as the total WLM exposure increases among the well over 400 dead uranium miners. The problem here is that no account was taken for the existence of the known latency period, so that the exposure received after the radiation damage which leads to lung cancer has not been excluded from the analysis. This omission would tend to cause a potentially large overestimation of the exposure required to cause the production of lung cancer. The final GEIS must therefore include a discussion of the latency period, and how the latency period has been treated in studies involving both acute and chronic low dose radiation experiments discussed in the scientific literature or otherwise relied upon by the Draft report.

6. The Appendix should contain a discussion of the methodology used in WASH-1400 to develop risk estimators and how this report is applicable to high-LET radiation problems. Specifically, this discussion should include an explanation of how (and why) WASH-1400 developed its three methods for estimating latent cancer deaths after a reactor accident. Also, this discussion should include the rationale, if any, for discarding the "relative risk" methodology of the BEIR report; the justification for calling the methodology which produces lower estimates of cancer fatalities the "upper bound" risk estimators; and the justification for resurrection of the "threshhold theory" of radiation and its related euphemism, the "dose rate effectiveness factors." Alternatively, all risk estimators from WASH-1400 should be discarded, and all references to WASH-1400 should be eliminated. All data from WASH-1400 should be thoroughly checked to insure that it is applicable to the high-LET radiations from this front end of the fuel cycle.

7. Since the avowed intent of the Draft is to place "conservative" bounds on cancer risk estimatos, some measure of the degree of conservatism used would be helpful. This could be accomplished by reference to the ranges of values of risk estimators, transfer coefficients, and dose conversion factors which have appeared in the open scientific literature, with some indication as to where the chosen values lie in a given range of values, In this way, the reader can decide for him-or herself whether the bounds are indeed "conservative."

8. The reason for discarding the "relative risk" estimators for bone cancer appears wholly arbitrary (page G-60). Outside the fact that its use would predict more bone cancer than the absolute risk method adopted, there ought to be a good reason to supply here.

9. Bearing in mind that for almost any insult, there is a latency period between the insult and the subsequent appearance of cancer or other consequences, and that cancer rates are increasing in the recent years at an accelerating rate, the use of unaltered 1970 cancer mortality data (Tables G-7.2, G-7.3, G-7.5, and ref. 6, Appendix G-7) is puzzling. Do not these data reflect insults which took place around 25 or more years ago?

10. What would the estimators of lung cancer in Table G-7.3 look like if the FRC value of 2.8 rads/WLM were employed instead of the arbitrary and unsupported value from the BEIR report (0.5 rads/WLM). How about the 20 rads/WLM value? Why were these values not even acknowledged to exist?

11. The risk estimator for bone cancer was taken from WASH-1400. How does this value compare with values reported in the open scientific literature?

12. In early 1978, Rossi and Mays, published a discussion of the variation of the RBE of high-LET radiations (neutrons) as a function of dose for induction of leukemia. They suggested that as the dose of neutrons decreases, the RBE increases (Health Physics, Vol. 34, pp. 353-60). How are these findings, which are wholly in keeping with the BEIR report and NCRP-43 comments referred to in comments on Appendix C, #1, incorporated into this report? How are the BEIR report and the NCRP-43 comments on the relationship of dose (and dose rate) and RBE included in this report?

13. It is now established that prior to the clinically observable symptoms of leukemia, many children contract and die from various infectious diseases (See Brit. J. Cancer 37 443-57 (1978)). Yet these deaths do not appear to be listed in Appendix G-7. Why not?

14. Many researchers now consider certain diseases of cerebral and coronary arteries associated with the growth of atherosclerotic plaques on the interior walls of the arteries to be tumorogenic. Is there a relationship between radiation and heart disease? A discussion of this relationship should be provided here.

15. The discussion of genetic risk estimators (G-63) is overly brief and very confusing. From where do the uncertainty factors arise? Do they reflect only uncertainty in the values in the BEIR report, or do they also include the frequently referenced (in the BEIR report) level of ignorance concerning the relationship between radiation and genetic effects? How are mild mutations included in the estimates of genetic risk estimators (BEIR report, p. 40)? How do high-LET radiation, like alpha particles, compare to x-rays and γ-rays in causing genetic damage? What experiments have been performed or are underway using alpha-radiation to determine genetic damage?

Appendix G-8

1. The numbers in most of the tables in this Appendix appear thoroughly Rasmussenized. (A number which has been Rasmussenized is one whose bands of uncertainty have been discarded at each succeeding level of presentation or manipulation). What are the error (or uncertainty) bands on the numbers in Tables G-8.1 through Table G-8.8?

2. These Tables are based on the 0.5 rad/WLM figure pulled out of thin air in the BEIR report (one can only assume). How would one scale them up to the FRC value of 2.8 rads, or the high BEIR value of 10 rads/WLM? Is the scale factor simply linear? How would the low dose and dose rate higher values of the RBE be included? Is the scale factor linear here, too? What happens to differing ventilation rates with changing seasons, differing dust levels, and so on?

Appendix J

1. The Staff technical position does not reflect a well considered or a permanent solution to the mill tailings problem. Rather, it represents a quick and dirty administrative attempt to postpone any real solution. It is permeated with loopholes, will do little on a long-term basis, and is even devoid of enforcement provisions. Is this the intent of these pseudo-regulations?

2. No mention is made in this Appendix about dose conversion factors, but it seems safe to assume that these are little different from those of Appendix G. If this is the case, then the Staff position is based on a significant underestimation of the inhalation problems associated with radon daughters (see my comments on Appendices G-5 and G-7).

Appendix K-6

1. In Table K-6.2, some constant value of recovery rate of U_3O_8 from ores of various grades appears to have been used. Is the recovery rate really independent of ore grade? Perhaps a table should be prepared which relates ore grade to recovery rate for the grades of ore which are expected to be mined to support the maximum anticipated number of nuclear power plants for their entire operational lifetime.

2. The subject of dirt covers for mill tailings piles receives only a cursory discussion in this Appendix. Lacking is discussion of the longevity of the proposed dirt cover, the ultimate fate of the mill tailings piles, and the total quantity of radon released to the air, particulates to the wind, and radium to the water over time for the full period of toxicity. It is disgraceful that the best disposal option the NRC seems willing to tentatively request that mill owners apply is one which has been in use for many millenia by felines -- the "pussy cat" method of waste disposal (wherein a little dirt is scrathed over the pile and the pussy cat promptly departs).

Appendix L

1. With the advantages of tailings disposal option VIII so obvious and overwhelming, it is disturbing in the extreme to see the NRC aim so low (Appendix J) in its proposed solution to the mill tailings problem. The "target criteria" and "upper limit criteria" are woefully lax, and reflect an unfortunate eagerness on the part of the NRC to recreate mill tailings problems such as those created by the AEC in Grand Junction, Colorado, only on a much more massive scale, and all with the illusion of security.

Appendix O

1. Table O-1 lists average radon flux measurements for a few locations in just five states. No mention is made of the local conditions at the time of measurement. Nor even is any discussion offered as to the time of year the measurements were taken. There are also no locations listed common to both Tables O-1 and O-2, so it is impossible to determine if there are any trends or correlations between radon flux and radium concentration. Why is the data base so sparse? These are the data from which one can only presume the estimated annual exhalation rate from soil is derived (see Table 5, Vol. 1).

2. This Appendix contains no discussion of the role played by seasonal variations on the natural radon exhalation rate, like the effect of temperature, moisture, snow cover, plant cover, etc. Yet from somewhere, by some method, somehow, someone has been able to come up with a value of 1.2 x 10[illegible] curies as the natural exhalation rate. Since this number is the one to which releases from uranium milling and tailings piles are compared, a discussion of the origin and accuracy of this number is

imperative.

Appendix R

1. The inspection-monitoring costs listed in Table R-1 seem plausible. The text, however, gives no indication as to how long this monitoring will have to be carried out in the future, or what will be the response if dangerous conditions are found in consequence of the inspection and monitoring. Additional information on these subjects should be included in the final report.

Appendix S

1. In the last paragraph on this page, the statement is made that the "tailings volume is inversely proportional to the ore grade." Is this strictly true? Does not the rate of recovery of uranium from the ore also depend at least partially on the grade of the ore? What would be the effect on disposal options of some proportional relationship between ore grade (in, say, percent, and the recovery rate?

2. In discussing the total fuel requirements, a cutoff at the year 2000 is made. This seems very arbitrary. Even if no further nuclear power plants are built, those operating then will continue to need fuel for the remainder of their operational lives, resulting in the production of additional mill tailings piles and of additional radon emissions. An arbitrary cutoff of discussion at the year 2000 is therefore quite unrealistic. What will be the total impact of this projected 380 GW(e) of nuclear generating capacity, even assuming no further construction of nuclear power plants? What about the uranium which will be needed, the number of mines, mills, etc., the change in ore grade, radon and particulate emissions, and the full range of health effects for the full period of the appropriate toxicity? In short, why is the discussion truncated in time, when the intent is to proceed beyond the year 2000 with the mining and milling of uranium? The final GEIS must address the full effects of all uranium production.

3. All previous comments made concerning the various aspects of computing health effects also apply here. The narrow ranges quoted here are ridiculous. As mentioned earlier, the dose conversion factor used in this Draft is more than a factor of 5 below one recommended by the Federal radiation Council ten years ago and a factor of 40 below the highest literature value, while only a factor of 5 above the very bottom literature value quoted in the BEIR Report. A much more candid discussion of cancers and other forms of radiation-induced premature deaths is due and must be added to the final GEIS.

4. For the reasons cited in the above arguments on the environmental dose commitment (Appendix G-6), the numbers of premature deaths contained in Table S-2 are confusing. Exactly what do they mean? Do radon emissions stop at the year 2000? For how long do they go on? What are the health effects for as long as they go on? Has the NRC really take a "hard look" -- much less a complete one -- at the front end of the uranium fuel cycle? The NRC is required to do so under the mandates of both the Atomic Energy Act and the National Environmental Policy Act.

General Comments on the Use of Models

Uranium mills have operated in the U.S. for well over 30 years and by now it would seem that their operations, environmental impacts, socioeconomic impacts, decommissioning and radiological impacts would be fairly well understood. However this does not seem to be the case at all. There is very little solid information on the past performances of uranium mills in this Draft GEIS. The reason for this large general omission is not clear, but it is tempting to speculate that the performance of uranium millers has been so poor that the NRC doesn't even want to talk about it. Such a problem would be far from unique in the history of the nuclear energy program (See my comments on Chapter 2).

This difficulty, if it indeed is one, has been avoided by the NRC in this Draft. There is very little in this Draft report which can be considered real, factual, or experimentally determined information. Instead, an unusually heavy reliance is placed on what are called "models." These "models" take on many forms, but their purpose seems to be to use some sort of guess work, mathematical or otherwise, to approximate a set of parameters; so one doesn't have to go out and measure the parameters or report what parameters are available. The table below lists most of the models used in this Draft:

Chapter	Subject described by a model
4	Climate, air quality, topography, land resources and their use, geology, mineral resources, water resources, hydrology, soils, biotic inhabitants, demography, economy, culture, politics, archeology, history, esthetics, and recreation.
5	The mill itself, wastes, radioactive emissions for gases and particulates.
6	Environmental impacts of mill operation on: in general, the items listed for Chapter 4, during construction, during mill operation, and, for a short period after mill operation. The discussion is repeated for a model cluster of uranium mills, including model continental radiological impacts.
7	Accidents at uranium mills.
8	Model technologies and techniques for mitigating environmental impacts of the model mills, including models for tailings disposal alternatives.
9	Environmental impacts of alternatives, including short term mill tailings disposal alternatives.
10	Post operational monitoring programs.
11	Monetary costs of alternatives.
12	Regulating criteria.
14	Costs of mill decommissioning and tailings management.

General Comments on the Use of Models, cont'd

Appendix	Subject described by a model
D	Water flow from mines.
E	Groundwater contamination from tailings ponds, seepage water velocities, and chemical compositions of seepage water.
F	Socioeconomic effects of mills, labor forces, personal distribution patterns.
G-1	Particulate deposition rates, radon diffusion rates through model soil.
G-2	Meteorology.
G-3	Ground concentrations of radioactive materials, concentrations in vegetation, meat, and milk, environmental dose committments, transfer coefficients.
G-5	Lung exposures by two models (ICRP, 1966 and UDAD computer code), inhalation dose conversion factors, ingestion doses, external dose conversion factors, food ingestion rates, ingestion dose conversion factors.
G-6	Regional exposures to radioactive effluents from mill, environmental dose committments.
G-7	Risk estimators for cancer and genetic effects.
O	Radon exhalation from natural soil.
P	Thickness of dirt required to reduce radon exhalation.

A reading of the text of the GEIS demonstrates that this profligate use of models has its costs. One of these costs is the production of a large lot of remodeled model numbers which come from other models. After so many of these trips through models, it becomes very questionable as to how much faith or trust can be put in any numbers in this report at all. Merely stating that numbers are conservative, overestimates, or whatever, is wholly insufficient. This is especially true when arbitrary low values from models are used as input for other models, as was shown in my comments on Appendix G. As indicated in my comments on Appendix S, which is incorrectly labeled a sensitivity analysis, an attempt is made to gloss over and conceal this problem; but in reality, this Appendix does not represent a full-blown sensitivity analysis in the true sense.

But the most troubling aspect of this entire process concerns the use and abuse of models to try to account for uncertainties, in the course of future events, among other things. When faced with the largest source of radioactive emissions in the entire nuclear fuel cycle - radon emissions from abandoned mill tailings piles - the NRC suddenly refuses even to model, to try to estimate, the health effects over the full period of toxicity of the tailings. The

NRC also balks at even presenting the numbers so the reader can make his or her own calculations.

Instead of a forthright, open, and candid discussion of this subject of primary importance, the NRC, in a complete about-face, now uses the very existence of uncertainties as an excuse to refrain from modeling long-term radon emissions and health effects. This about-face comes even after the NRC had so underestimated the health effects due to radon. The reason, of course, is that with almost any model, the numbers of curies of radon released and the resulting premature deaths quickly mount to astronomical proportions. (The third attachment to these comments shows the calculations done by the NRC staff on potential radon emissions).

The solution to the problem of the long-term radon emissions from mill tailings piles, in the eyes of the NRC, is to ignore the problem by citing uncertainties with regard to future climatic conditions, for example, as a justification for refusing to do any modeling at all. One alternative disposal method which the NRC superficially considers, and then discards for invented reasons, is to do the job right and insure that the radon is forever prevented from entering the biosphere - alternative 8. In fact, that there are uncertainties in conditions in the future is most notable an indictment of the approach favored by the NRC in order to keep the short term cost of uranium milling and milltailings disposal artificially low. The NRC's "proposed solution," as outlined in the Draft GEIS and the proposed guidelines, represents nothing more than a continuing commitment to the attitudes that led to the epidemic of lung cancer among early uranium miners, which continues to this day.

The NRC must instead use the uncertainties about future conditions to weigh its proposed mill tailings disposal options, and then to discard those which did not lead to the resolution of the uncertainties. In the continuing disgraceful tradition of applications of fission technology, the NRC has chosen to uphold tradition, and to protect, cover for, and actively promote the nuclear industry at an unparalleled and unprecedented cost in human lives.

Were there no other glaring deficiencies in this Draft, this conscious condemnation of untold millions, billions, or more, of yet unborn humans to early and unpleasant illness and death is sufficient justification for a complete rejection of this Draft document. But this is only the largest deficiency; there are many others, only some of which have been identified here. Other commenters will undoubtedly identify additional deficiencies, which will enlarge upon the inadequacies highlighted here.

A thorough explanation of the points raised in these general comments on the use, abuse, and non-use of models is absolutely necessary in the final GEIS.

Discussion

The distortion of accepted knowledge begins early in the Draft. In Appendix C, page 2, the NRC attempts to apply concepts which are debatable for x-rays, γ-rays and beta particles, called low LET radiations, to alpha particles, which are high LET radiations. In the third full paragraph on this page, the ghost of the long dead "threshhold theory" of radiation is raised, along with the unproven idea of cellular repair mechanisms to repair the damage caused by low LET radiation. As the NRC is well aware, the radiation problems caused by the mining and milling of uranium are primarily due to alpha particles, or high LET radiation, to which the stated considerations on page 2 of Appendix C do not apply.

In fact, it is a reasonably well established principle that when the dose of high LET radiation is decreased, the RBE increases, and is not represented by a constant value. This principle is not even acknowledged in the Draft. In the Draft, an arbitrary value of the RBE of 10 is used throughout, even though its variable nature has been discussed for years. The Final Statement on milling would be greatly improved if it contained a discussion of the current status of knowledge and controversy which is applicable to high LET radiation.

The necessity of a more candid discussion than the Draft report provides is further borne out by the subsequent use of the concept of the "working level" (WL) in Appendix C. The brief and distorted discussion in the Draft falls far short of being a balanced presentation. It does not, for instance, mention the reasons offered by active researchers in the field as to why the WL is an inappropriate measure of either radon daughter concentration or dose.

It must also be observed that in making the conversion from an exposure of one WL under conditions as yielding a dose of 5 rem (Appendix C, page 4), the reader is referred to the BEIR report and Appendix G. Upon turning to Appendix G for details, the reader is again referred only to the BEIR report. But that report is grossly misrepresented on page 45 of Appendix G. Here the Draft Report states

> "The BEIR Report presents a detailed discussion of radon daughter dosimetry..." (footnote omitted)

However, when the section of the BEIR report which discusses radon is consulted. the discussion in that report is seen to be exceedingly superficial. Worse yet. the conversion factor of 0.5 rad per WL month (WLM) used in the BEIR report itself does not even come from the numerous values in the published scientific literature.

On page 44 of Appendix G, the NRC refers to an EPA report published in 1973 (ref. 9). In that report, which the then Atomic Energy Commission chose to ignore in its 1974 version of its "Environmental Effects of the Nuclear Fuel Cycle," a fairly detailed discussion of radon dosimetry is given by the EPA. However, since the conclusions of the EPA report do not coincide with the preconceived notions of the NRC, they were apparently ignored.

These omissions and misrepresentations are by no means small or trivial. They indicate just how far the NRC will go to protect and cover for the industry it is supposed to regulate. It is difficult to conclude that these mistakes, like underestimating the value of the RBE of alpha particles or underestimating the dose due to radon daughters were unconscious or accidental. If indeed they were accidental, one would expect an approximately equal number of genuine overestimations of doses and effects. Such is not the case, as the NRC, like its predecessor agency, traditionally and unfailingly errs on the side of the nuclear industry to the detriment of the health and safety of the public.

On page 58 of Appendix G, the staff states that the relative risk model fits lung cancer data from the uranium mines better than the absolute risk model. This postion was first advanced by Drs. John Goburan and Arthur Tamplin about 10 years ago, at which time it was contested by the AEC. Yet when the NRC calculates a risk estimator for radon daughter exposure on page 60 of Appendix G, it includes risk estimators it acknowledged two pages earlier to be inappropriate lung cancer estimators. The inclusion of the two inappropriate estimators had the effect, not surprisingly, of lowering the calculated number of fatal cancers.

Table G-7.4 lists an assumed value of 15 years for the latency period for lung cancer from radon daughters. Whether this value is anywhere near correct is not really known, because in the studies that have appeared in the scientific literature, from studies in the U.S. and Eastern Europe, latency periods were not included in deriving the reported dose-response analyses. In the usual treatment, the entire exposure of the unfortunate workers is used as the value to calculate the exposure which caused cancer. Generally, these workers continued to work one or two years prior to the time they died of cancer. Thus the use of the entire exposure history of the workers without some accounting for the latency period overestimates the exposure required to produce lung cancer by a substantial margin, and contributes to the general underestimation of the risk of lung cancer due to radon exposure.

Furthermore, the NRC staff states in Appendix G, page 58, that low levels of radiation exposure are difficult to detect because of long latency periods and low probabilities of occurrence of cancers. It has been shown however, among the uranium miners in the U.S., that latency periods for low exposure to radon daughters are shorter than that for high exposures. The unswerving bias of the NRC toward protecting the nuclear industry at the expense of the public health and safety is particularly evident here (Appendix G, page 58), where the NRC assumes long latency periods, contrary to available experimental data, and low probabilities of occurrence of cancers due to low level radiation. Apparently the NRC has left no stone unturned in its quest to underestimate the risks of cancer from the uranium mining and milling processes.

In Chapter 12 of the Draft, page 25, the NRC assumes that even if the proposed coverings of mill tailings piles do erode away,

> ...remedial action could be taken in a
> time frame that would prevent any adverse
> health effects to the maximally exposed individuals.

The NRC leaves the public in the dark as to how anyone could detect problems at the abandoned tailings piles which occurs far off into the future, such as 100, 1000, or 10,000 years from now. After all, even with all of our technology and modern epidemiological capabilities, we are still unable to pinpoint the major causes of cancer today, let alone any national increases in cancer mortality. How does the NRC expect future societies, whose capabilities may or may not exceed ours today, to be able to detect a <u>local</u> increase in cancer mortality due to radon emissions from todays milling activities? The Draft contains no discussion of this question. Apparently the NRC sees no inconsistency by assuming, on one hand, that the effects of low-level radiation occur with low probability, and, on the other hand, that future peoples, with unknown levels of technological competence, can detect the effects of low level radiation and respond in a manner which we are unable to do today.

In Appendix 5, page 1, the statement is made that the tailings volume is proportional to the ore grade. This statement is true if the degree of recovery of uranium from the ore is a constant. However, there is no reason to expect that the level of uranium recovery is constant. As a result, it is reasonable to assume that the volume of tailings will be greater than that conveniently assumed by the NRC.

On this same page, the NRC states also that the activity of the tailings is proportional to the grade of the ore. However, as the ore grade drops, the total activity of the tailings required to be created to supply one year's fuel for a reactor will increase, due to the increasing amounts of uranium not recovered from the ore. In addition, as more uranium is left in the ore and the volume of tailings mounts faster than the inverse proportionality incorrectly assumed by the NRC, the duration of the problem of radon emissions shifts from a problem centered on the 80,000 year half-life of thorium-230 to a problem with a 4.5 billion year half-life.

The Draft report would benefit enormously from a thorough and candid discussion of these items and the more detailed remarks made in the precedings sections above. The final GEIS should also explain why the NRC so consistently seems to underestimate the adverse effects of radiation on man.

Conclusion

Our past experiences with the NRC Staff lead us to believe that the many crucial omissions, deceptive misstatements, and outright lies of the Draft GEIS reflect a conscious and deliberate NRC policy to jeopardize the public health and safety and thwart the objectives of NEPA. We come to this conclusion because the slaughter of human lives resulting from radon emissions from the mill tailings piles has been the principal focus of an extensive, consolidated NRC licensing proceeding for over two years. Throughout this period, through our member groups, we have actively participated in this still ongoing and yet unresolved consolidated licensing proceeding. Furthermore, it was citizen intervenors, rather than the NRC Staff or any applicant who first raised the radon issue.

Virtually all of the detailed remarks we have made here, we have already, repeatedly, made during the ongoing consolidated radon licensing proceeding, without any apparent impact whatsoever upon either the Draft GEIS or the NRC Staff. To illustrate the kind of comments submitted throughout this ongoing radon proceeding, and thereby further impugn the NRC Staff's actual motives, we append to and incorporate in these comments two documents from the consolidated radon proceeding. Furthermore, we append and incorporate in these comments certain pages from the GESMO proceeding which demonstrate the fact that the NRC Staff has been fully aware of the full dimension of the radon problem for several years. Tragically, the Staff apparently is party to a macabre conspiracy to condemn an untold and prodigious number of the yet unborn to an increased level of ill health and premature death.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING APPEAL BOARDS

Alan S. Rosenthal, Chairman
Dr. John H. Buck
Michael C. Farrar
Richard S. Salzman
Dr. W. Reed Johnson
Jerome E. Sharfman

February 19, 1979

In the Matters of

METROPOLITAN EDISON COMPANY *et al.*	Docket No. 50-320
(Three Mile Island Nuclear Station, Unit No. 2)	
PHILADELPHIA ELECTRIC COMPANY *et al.*	Docket Nos. 50-277, 50-278
(Peach Bottom Atomic Power Station, Units 2 and 3)	

and

Docket Nos.	50-338	STN 50-482
	50-339	STN 50-484
	50-354	STN 50-485
	50-355	STN 50-491
	50-389	STN 50-492
	50-400	STN 50-493
	50-401	STN 50-518
	50-402	STN 50-519
	50-403	STN 50-520
	50-443	STN 50-521
	50-444	STN 50-546
	50-482	STN 50-547
	50-500	
	50-501	
	50-513	
	50-553	
	50-554	

IN RESPONSE TO THE DE MINIMUS THEORY AND ALAB-509

In ALAB-509, the Atomic Safe

Board") requires that the Interven

UNITED STATES OF AMERICA
NUCLEAR REGUL TORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING APPEAL BOARDS

In the Matters of	)	
	)	
PHILADELPHIA ELECTRIC COMPANY et al. (Peach Bottom Atomic Power Station, Units 2 and 3)	)	Docket Nos. 50-277 50-278
METROPOLITAN EDISON COMPANY et al. (Three Mile Island Nuclear Station, Unit No. 2)	)	Docket No. 50-320
PUBLIC SERVICE ELECTRIC AND GAS CO. (Hope Creek Generating Station, Units 1 and 2)	)	Docket Nos. 50-354 50-355
NORTHERN STATES POWER COMPANY et al. (Tyrone Energy Park, Unit 1)	)	Docket No. STN 50-484
ROCHESTER GAS AND ELECTRIC CORPORATION et al. (Sterling Power Project, Nuclear Unit 1)	)	Docket No. STN 50-485

Affidavit of Dr. Chauncey Kepford Setting Forth the Intervenors' Statement of the Facts as to Which There is a Material Dispute.

Chauncey Kepford, being duly sworn, states as follows:

1. I am a member of the Executive Board of the Environmental Coalition on Nuclear Power. I serve also as a consultant to this organization and its member groups on legal and technical matters. I have appeared as an expert witness on the radon issue on behalf of the intervening citizen groups ("Intervenors")in the TMI-2 licensing proceedings. I also have appeared as an expert witness on the radon issue on the behalf of citizen intervenors in the Perkins 1, 2, and 3 proceedings.

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7910190230
(film this one)

2. This affidavit was prepared by me for the purpose of establishing before the Appeal Board that there are material facts as to which there is a dispute in this proceeding. The comments herein will refer specifically to the numbered paragraphs of the Applicant's "Statement of Material Facts as to Which There is no Genuine Issue to be Heard" ("Statement") and the "Affidavit of Morton I. Goldman" ("Goldman").

3. The use by the Staff of a value of 2.71×10^5 metric tons (MT) of uranium ore per reactor year is inaccurate to the extent that it defines a quantity of ore of a certain (unstated) set of reactor parameters (Statement, at 7). In reality, the average grade of ore being mined in the U.S. has dropped significantly in recent years and there is no reason to expect that it will not continue to decline as higher grades of ore are depleted.

4. The ore grade problem is complicated by the fact that as the ore grade drops, the percentage of material to be recovered from the ore drops also. What this means is that 10^5 tons of 0.2% U_3O_8 ore does not, after milling, produce the same quantity of recovered U_3O_8 as would 10^6 tons of 0.02% U_3O_8 ore. In fact, it would take more of the 0.02% ore, because a lower level of recovery of U_3O_8 would be realized. Since more of the lower grade ore will have to be mined than the 10^6 tons, a larger radon-222 source term may result per reactor year, in addition to having the problem of stabilizing more than 10 times the volume and weight of the mill tailings than for the 0.2% ore. Compare Statement, para. 49, 50, Goldman, para. 22, 23.

5. The assumption that deep mines produce no radon gas after shutdown (Statement 6,8) cannot be accepted as correct. A reading of the Perkins transcript cited (tr. 2542) shows clearly that Witness Wilde acknowledged that natural

ventilation could bring up radon from the mine interior to the external environment.

Neither the TMI-2 nor the Perkins proceedings addressed the question of how long whatever "seals" which are applied to underground mines would be effective at containing all radon emissions within the mines.

6. The Perkins record contains a wholly inadequate examination of radon-222 releases from openpit mines (Statement, at 9-11, 15, 16, 17, 18). The calculations offered by the Applicant are based on sweeping and unsubstantiated assumptions; they are not firmly based on experimental evidence. In addition, Witness Wilde freely admitted his calculation was "quick and dirty" (tr. 2610). Furthermore, Witness Goldman used an overburden in his calculation with an apparent volume of 270,000 MT (tr. 2640), just that of one year's requirements. This value is refuted in his own affidavit (Goldman, 12). Contrary to the Statement in his affidavit (Goldman, 11) that his Perkins calculations included open pit mine emissions, the 100 curie and 200 curie values refer to emissions of radon from the overburden for two specific uranium concentrations (tr. 2640, 19-13).

7. Radon-222 is a naturally-occurring radioactive decay product in the middle of a radioactive decay series which begins with uranium-238 and terminates with stable lead-206. Radon-222 is of particular concern for a number of reasons:

(a) While radon-222 has a short, 3.8 day half-life, it has parent radioactive materials with long half-lives: uranium-238 (4.5 billion years) and thorium-230 (80,000 years).

(b) Radon is the only naturally-occurring radioactive noble gas, and radon-222 is the only naturally-occurring radon isotope with a half-life longer than about one minute. As a result, radon-222 has by far the greatest opportunity to diffuse away from its point of origin prior to undergoing decay.

(c) Radon-222 has three short-lived daughter products which emit alpha particles, which are among the most damaging of the ionizing radiations. These daughter products, when inhaled, are known to cause lung cancer.

8. In the process of obtaining fuel for nuclear reactors, naturally-occurring uranium ore is taken to mills where the ore is ground, about 90% of the uranium is removed, and the "tailings" are washed out to a pond where, when the mill ceases operation, the tailings dry and radon, which otherwise would have been trapped in underground ore formations, can escape to the air. Once the radon is in the air, it can be transported with the winds and taken far from the mill tailings dump.

9. In the case of a mill tailings dump, the primary "parent" of radon-222 is thorium-230, since about 90% of the uranium-238 is generally removed during the milling process. This means that the emission of radon will be governed primarily by a source with an 80,000 year half-life. Of course, when much of the thorium-230 has decayed, e.g., after about 3 half-lives, or 240,000 years, the main parent then becomes the very long half-lived uranium-238.

10. While the annual emissions of radon from the mill tailings used to supply fuel to a commercial nuclear reactor for one year are appreciable, about 74.5 curies to 100 curies when this annual emissions rate is integrated over time, the total emission is seen to be truly enormous. In the case of TMI-2, the radon which will be produced by the radioactive decay of the remaining thorium-230 in the abandoned mill tailings piles is about 320 million curies of radon. If the decay of the remaining 10% of uranium-238 not removed by the milling process is considered, the radon produced for each year of TMI-2 operation increases to about 1.8 trillion curies. It must be emphasized that these emissions are the result of natural decay of the thorium and uranium in the tailings piles produced to operate a commercial reactor for <u>one</u> year.

11. During the TMI-2 licensing proceeding, the NRC, through the testimony of its witness, Gotchy, used a death rate of 0.023 premature deaths for each 4800 curies of radon released to the atmosphere. From this value, a number can be computed for the premature deaths caused by these radon emissions due to operation of a commercial reactor such as TMI-2. Gotchy's calculations assumed a future population model which, in essence, freezes the present society at a particular population level and extends it as far as necessary into the future. On this basis, a value of 87,000 premature deaths for each year of operation of TMI-2 can be computed.

12. Using a conversion factor from curies emitted to deaths due to cancer derived by the EPA, which essentially differs from Gotchy's conversion factor in that it uses a different lung dosimetry model, a value of 1.2 million premature deaths is calculated for each year that TMI-2 will operate.(See testimony of Dr. Chauncey Kepford in the TMI-2 licensing proceeding.)

13. An additional issue in calculating the cost in human lives of the radon emissions concerns the dosimetry of radon daughters in the human lung. This dosimetry is complicated by the fact that radon concentrations vary widely in the natural environment. In general, it is areas of more static air where the daughters of radon have a chance to accumulate. Such more static conditions are more typical of underground uranium mines and, for even lower concentrations, the interiors of buildings.

14. Among researchers in the field, there does not seem to be an agreed upon value for "typical" radon daughter concentrations for a given radon concentration. Nor is there a generally agreed upon depth of penetration by the emitted alpha particles into the sensitive tissue of the lung. As a result of these and other factors, there exists a wide range of factors which may be used to convert from a given exposure to a given concentration of radon into a radiation dose in the proper units, as rads or roentgens. The NRC Staff uses a

value near the low end of the published range, reducing the effect of any calculated dose.

15. Furthermore, it has recently been suggested that a number called the "relative biological effectiveness", or RBE, which converts rads or roentgens into the more customary unit, rems, may be underestimated by a large factor, perhaps 19 or more, for low doses of high LET radiation ("Leukemia Risk from Neutrons", Rossi and Mays, Health Physics 34 p. 353-60, 1978). The result of these above considerations (of dosimetry and low-level radiation effects) suggests that the above numerical estimates of premature deaths due to radon may be underestimated by a factor of at least 100.

16. In addition to the 1.2 million or so avoidable, premature deaths attributable to the mill tailings emissions of radon for each year of commercial operation of a single nuclear reactor (based upon EPA's conversion factor), and in addition to the factor of 100 underestimation which this enormous number of deaths may represent (as explained above), one must also consider the radon-related deaths attributable to the mining of uranium ore (Perkins tr. 2465-67). The prospects of serious mine reclamations efforts which would substantially reduce the long-term radon emissions attributable to the mining portion of the nuclear fuel cycle appear dim or non-existent. (See, e.g., Dr. Chauncey Kepford's February 19, 1979, response to the de minimus theory, at pages 10-16). Neither of these sources of radon-222 is small, insignificant, or de minimus.

Chauncey Kepford

Dr. Chauncey Kepford
433 Orlando Avenue
State College, Pa. 16801

Sworn to and subscribed to before me this 26th day of June, 1979.

My Commission expires 03/16/81

Jean B. Harris

Jean B. Harris, Notary Public
State College, Centre County, Pa. 16801
My Commission Expires March 16, 1981

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE GESMO HEARING BOARD

In the Matter of GENERIC ENVIRONMENTAL STATEMENT ON MIXED OXIDE FUEL	)))))	Docket No. RM-50-5

CERTIFICATE OF SERVICE

I hereby certify that copies of NRC STAFF'S WRITTEN ANSWERS TO QUESTIONS ON CHAPTER IV F AND G (INCLUDING 7 ANSWERS PERTAINING TO IV E) in the above captioned matter have been served on the December 6, 1976 Service List, by deposit in the United States mail, first class or air mail, or, as indicated below, through deposit in the Nuclear Regulatory Commission's internal mail system, this 13th day of December, 1976.

Ms. Kathleen M. Mason
Special Assistant for GESMO
Office of the Secretary
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Docketing and Service Section
Office of the Secretary
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

William J. Olmstead
William J. Olmstead
Counsel for NRC Staff

PARTICIPANT: Natural Resources Defense Council

SUBPARAGRAPH: Chapter IV F, Summary

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Questions

1. On page IV F-4 it is stated that one of the significant effects of recycle for the period 1975 through 2000 is:

   " - Reduction of ^{222}Rn emissions by about 2,500,000 curies due to uranium recycle and by about 5,300,000 curies due to recycling both uranium and plutonium."

   How many additional curies would be released in the 1 million years following 2000, from the same quantity of uranium ore represented by the source of the 2,500,000 curies? How many between 2000 and infinity?

   On page NF-5 it is stated:

   " - Decrease in the release of ^{222}Rn from active mill tailings areas of about 470,000 curies with uranium recycle and a total reduction of about 990,000 curies with recycle of both uranium and plutonium."

2. How many additional curies would be released in the 1 million years following 2000, from the same quantity of mill tailings represented by the source of the 470,000 curie?

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Answer

1. The quantity of ore which constitutes the source of the 2,500,000 curies of ^{222}Rn referred to in this question is approximately 170×10^6 MT with an average grade of 0.1% U_3O_8.

   The amount of ^{222}Rn that would be released from this quantity of ore during the time periods specified would depend on the conditions under which the release is postulated to occur.

   If it is assumed that the ore remains in place, undisturbed in its natural geological setting, essentially all of the ^{222}Rn ($T_{1/2}$ = 3.82 days) would decay in the time required for diffusion transport of the ^{222}Rn from its source at a depth of a few hundred feet underground to the surface of the earth. In this case the amount of ^{222}Rn released to the environment would approach zero as a lower limit.

   The maximum amount of ^{222}Rn release would occur if it is assumed that the ore is distributed at the surface of the earth in a physical form such that all of the ^{222}Rn formed by radioactive decay is released immediately to the environment. This case would define the absolute upper limit for ^{222}Rn release.

   The upper limit values can be calculated for the time periods of interest by using the radioactive decay equation $N = N_0 e^{-\lambda t}$ and the following physical constants:

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Answer (Cont'd)

Atomic Mass ^{238}U = 238 gm
Atomic Mass ^{222}Rn = 222 gm
Specific Activity $^{238}U = 3.33 \times 10^{-7}$ Ci/gm
Specific Activity $^{222}Rn = 1.54 \times 10^{5}$ Ci/gm
$T_{1/2}$ $^{238}U = 4.51 \times 10^{9}$ years
λ (decay constant) $^{238}U = 1.54 \times 10^{-10}$ $year^{-1}$

Calculations are as follows for the maximum curies of ^{222}Rn released from 170×10^{6} MT of 0.1% U_3O_8 ore:

Amount of ^{238}U originally present in 170×10^{6} MT of 0.1% U_3O_8 ore

$$(170 \times 10^{6}MT)(10^{6}\ gm/MT)(1 \times 10^{-3}\ gm\ U_3O_8/gm)(0.848\ gm\ ^{238}U/gm\ U_3O_8) = \underline{\underline{1.44160 \times 10^{11}\ gm\ ^{238}U}}$$

Amount of ^{238}U in 170×10^{6} MT after 10^{6} years decay time

$$N = N_0e^{-\lambda t}$$
$$N = 1.44160 \times 10^{11}\ e^{-(1.54 \times 10^{-10})(10^{6})}\ e$$
$$N = \underline{\underline{1.44138 \times 10^{11}\ gm\ ^{238}U}}$$

Amount of ^{238}U which decayed in 10^{6} years

$$(1.44160 \times 10^{11}) - (1.44138 \times 10^{11}) = \underline{\underline{2.2 \times 10^{7}\ gm\ ^{238}U}}$$

Amount of ^{222}Rn formed by decay of 2.2×10^{7} gm ^{238}U

$$(2.2 \times 10^{7}\ gm\ ^{238}U)\ \frac{(222\ gm\ ^{222}Rn)}{(238\ gm\ ^{238}U)} = 2.05 \times 10^{7}\ gm\ ^{222}Rn$$

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Answer (Cont'd)

Curies of ^{222}Rn formed and released in 10^6 years - upper limit

$$(2.05 \times 10^7 \text{ gm } ^{222}Rn)(1.54 \times 10^5 \text{ Ci } ^{222}Rn/\text{gm } ^{222}Rn) = \underline{\underline{3.16 \times 10^{12} \text{ Ci } ^{222}Rn}}$$

Calculations are as follows for the maximum curies of radon released in an infinite number of years:

In this case all of the ^{238}U originally present in the ore will decay in an infinite period of time. Therefore, the amount of ^{238}U which decays is simply $\underline{\underline{1.4416 \times 10^{11} \text{ gm } ^{238}U}}$.

Amount of ^{222}Rn formed by decay of 1.4416×10^{11} gm ^{238}U.

$$(1.4416 \times 10^{11} \text{ gm } {}_3O_8) \left(\frac{222 \text{ gm } ^{222}Rn}{238 \text{ gm } ^{238}U}\right) = 1.34 \times 10^{11} \text{ gm } ^{222}Rn$$

Curies of ^{222}Rn formed and released in an infinite number of years - upper limit

$$(1.34 \times 10^{11} \text{ gm } ^{222}Rn)(1.54 \times 10^5 \text{ Ci } ^{222}Rn/\text{gm } ^{222}Rn) = \underline{\underline{2.06 \times 10^{16} \text{ Ci } ^{222}Rn}}$$

Curies of ^{222}Rn Released in Time Period

	10^6 years	infinite years
Lower Limit	0	0
Upper Limit	3.16×10^{12}	2.06×10^{16}

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Answer (Cont'd)

The amount of ^{222}Rn which is released to the environment will depend on the assumptions that are made concerning the conditions under which such a release would occur, that is, what fraction of the radon formed is assumed to enter the atmospheric environment. The upper limit values from the table above can be multiplied by the assumed fractional release to obtain the projected release of ^{222}Rn from 170 x 10^6 MT of 0.1% U_3O_8 ore during the time period of interest.

2. The quantity of tailings which constitutes the source of the 470,000 curies of ^{222}Rn referred to in the second part of this question is approximately 170 x 10^6 MT of tailings.

An approach similar to that used in the answer to the previous part of this question can be used to calculate the amount of ^{222}Rn released during 10^6 years, except that in this case the fractional amount of radon can also be calculated.

Calculations are as follows for the curies of ^{222}Rn released from 170 x 10^7 MT of tailings in 10^6 years.

Fraction of ^{222}Rn released from 170 x 10^6 MT of tailings (same basis as GESMO model mill and tailings pile).

Curies of ^{222}Rn released per year per MT of tailing (GESMO model mill)

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Answer (Cont'd)

$$\frac{2797 \text{ Ci } ^{222}\text{Rn/yr}}{(3500 \text{ MT/day})(300 \text{ day/yr})(26 \text{ years})} = \underline{1.02 \times 10^{-4} \text{ Ci } ^{222}\text{Rn/yr MT tailings}}$$

$$(170 \times 10^{6} \text{ MT})(1.02 \times 10^{-4} \text{ Ci } ^{222}\text{Rn/yr MT}) = \underline{\underline{1.734 \times 10^{4} \text{ Ci } ^{222}\text{Rn/yr}}}$$

Curies of ^{222}Rn formed per year by decay of ^{226}Ra in 170 x 10^{6} MT of tailings

^{226}Ra activity = 2.82×10^{-4} Ci ^{226}Ra/MT
Atomic Mass ^{226}Ra - 226 gm
Atomic Mass ^{222}Rn - 222 gm
Specific Activity ^{226}Ra = 1 Ci/gm
Specific Activity ^{222}Rn = 1.54×10^{5} Ci/gm
$T_{1/2}$ ^{226}Ra = 1602 years
$\lambda\ (^{226}\text{Ra}) = 4.33 \times 10^{-4}\ \text{year}^{-1}$

Amount of ^{226}Ra originally present in 170 x 10^{6} MT of tailings

$$(1.70 \times 10^{8} \text{ MT})(2.82 \times 10^{-4} \text{ Ci } ^{226}\text{Ra/MT}) = 4.794 \times 10^{4} \text{ Ci } ^{226}\text{Ra}$$
$$= \underline{4.794 \times 10^{4} \text{ gm } ^{226}\text{Ra}}$$

Amount of ^{226}Ra present in 170 x 10^{6} MT of tailings after one year decay time

$$N = N_0 e^{-\lambda t}$$
$$N = 4.794 \times 10^{4} e^{-(4.33 \times 10^{-4})(1)}$$
$$N = \underline{4.7919 \times 10^{4} \text{ gm } ^{226}\text{Ra}}$$

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Answer (Cont'd)

Amount of ^{226}Ra which decayed in one year

$$(4.7940 \times 10^4)-(4.7919 \times 10^4) = \underline{21 \text{ gm } ^{226}Ra/yr}$$

Amount of ^{222}Rn formed by decay of 21 grams of ^{226}Ra in one year

$$(21 \text{ gm } ^{226}Ra)\left(\frac{222 \text{ gm } ^{222}Rn}{226 \text{ gm } ^{226}Ra}\right) = 20.63 \text{ gm } ^{222}Rn/yr$$

Curies of ^{222}Rn formed by decay in one year

$$(20.63 \text{ g } ^{222}Rn/yr)(1.54 \times 10^5 \text{ Ci } ^{222}Rn/gm\ ^{222}Rn) =$$

$$\underline{3.177 \times 10^6 \text{ Ci } ^{222}Rn/yr}$$

Fraction of ^{222}Rn formed by decay which is released from tailings

$$\frac{1.734 \times 10^4 \text{ Ci } ^{222}Rn/yr}{3.177 \times 10^6 \text{ Ci } ^{222}Rn/yr} = \underline{\underline{\begin{array}{c}5.46 \times 10^{-3} \\ \text{(fraction released)}\end{array}}}$$

During the million year interval of interest the amount of ^{222}Rn present in the tailings, and thus the amount of ^{222}Rn released will be controlled first by the decay of the once removed parent ^{230}Th activity, and later, after the ^{230}Th has decayed to about 10% of its original activity (equal to the ^{238}U activity of the tailings), by the decay of the parent ^{238}U of the series.

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Answer (Cont'd)

The first interval during which ^{230}Th decay controls ^{222}Rn release is about 3.3 half-lives of ^{230}Th ($T_{1/2}$ = 80,000 years) or 264,000 years.

^{230}Th activity = 2.82×10^{-4} Ci ^{230}Th/MT

Atomic Mass ^{238}U - 238 gm

Atomic Mass ^{230}Th - 230 gm

Atomic Mass ^{222}Rn - 222 gm

Specific Activity ^{238}U = 3.33×10^{-7} Ci/gm

Specific Activity ^{230}Th = 1.94×10^{-2} Ci/gm

Specific Activity ^{222}Rn = 1.54×10^{5} Ci/gm

$T_{1/2}$ ^{230}Th = 8.0×10^{4} years

λ ^{230}Th = 8.66×10^{-6} year^{-1}

$T_{1/2}$ ^{238}U = 4.51×10^{9} years

λ ^{238}U = 1.54×10^{-10} year^{-1}

Amount of ^{230}Th originally present in 170×10^{6} MT of tailings

$$\frac{(2.82 \times 10^{-4}\ \text{Ci}\ ^{230}\text{Th/MT})(1.7 \times 10^{8}\ \text{MT})}{(1.94 \times 10^{-2}\ \text{Ci}\ ^{230}\text{Th/gm})} = \underline{2.47 \times 10^{6}\ \text{gm}\ ^{230}\text{Th}}$$

Amount of ^{230}Th in 170×10^{6} MT of tailings after 2.64×10^{5} years of decay time

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Answer (Cont'd)

$$N = N_0 e^{-\lambda t}$$

$$N = 2.471 \times 10^6 e^{-(8.66 \times 10^{-6})(2.64 \times 10^5)}$$

$$N = \underline{2.51 \times 10^5 \text{ gm } ^{230}\text{Th}}$$

Amount of ^{230}Th which decayed in 2.64×10^5 years

$$(2.471 \times 10^6 \text{ gm } ^{230}\text{Th}) - (2.51 \times 10^5 \text{ gm } ^{230}\text{Th}) = \underline{2.22 \times 10^6 \text{ gm } ^{230}\text{Th}}$$

Amount of ^{222}Rn formed by decay of 2.22×10^6 gm ^{230}Th

$$(2.22 \times 10^6 \text{ gm } ^{230}\text{Th})\left(\frac{222 \text{ gm } ^{222}\text{Rn}}{230 \text{ gm } ^{230}\text{Th}}\right) = 2.14 \times 10^6 \text{ gm } ^{222}\text{Rn}$$

Curies of ^{222}Rn formed from ^{230}Th decay in 2.64×10^5 years

$$(2.14 \times 10^6 \text{ gm } ^{222}\text{Rn})(1.54 \times 10^5 \text{ Ci/gm } ^{222}\text{Rn}) = \underline{3.30 \times 10^{11} \text{ Ci } ^{222}\text{Rn}}$$

Curies of ^{222}Rn released from ^{222}Rn formed from ^{230}Th decay during 2.64×10^5 years

$$(3.3 \times 10^{11} \text{ Ci } ^{222}\text{Rn})(5.46 \times 10^{-3}) = \underline{\underline{1.80 \times 10^9 \text{ Ci } ^{222}\text{Rn}}}$$

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Answer (Cont'd)

During the entire million-year interval ^{222}Rn will also be formed by decay of ^{238}U and released from the tailings pile

Amount of ^{238}U originally present in 170×10^6 MT of tailings would be 9.5% of the amount of ^{238}U in the ore (90.5% mill recovery)

$$(1.44160 \times 10^{11} \text{ gm } ^{238}U)(0.095) = \underline{1.36952 \times 10^{10} \text{ gm } ^{238}U}$$

Amount of ^{238}U in 170×10^6 MT of tailings after one million years of decay time

$$N = N_o e^{-\lambda t}$$

$$N = 1.36952 \times 10^{10} e^{-(1.54 \times 10^{-10})(10^6)}$$

$$N = \underline{1.36931 \times 10^{10} \text{ gm } ^{238}U}$$

Amount of ^{238}U which decayed in 10^6 years

$$(1.36952 \times 10^{10})-(1.36931 \times 10^{10}) = \underline{2.1 \times 10^6 \text{ gm } ^{238}U}$$

Amount of ^{222}Rn formed by decay of 2.1×10^6 grams ^{238}U

$$(2.1 \times 10^6 \text{ gm } ^{238}U) \frac{(222 \text{ gm } ^{222}Rn)}{(238 \text{ gm } ^{238}U)} = \underline{1.96 \times 10^6 \text{ gm } ^{222}Rn}$$

Curies of ^{222}Rn formed in 10^6 years from ^{238}U decay

$$(1.96 \times 10^6 \text{ gm } ^{222}Rn)(1.54 \times 10^5 \text{ Ci } ^{222}Rn/\text{gm}) = \underline{3.02 \times 10^{11} \text{ Ci } ^{222}Rn}$$

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Answer (Cont'd)

Curies of ^{222}Rn released from ^{222}Rn formed from ^{238}U decay in 10^6 years

$$(3.02 \times 10^{11} \text{ Ci } ^{222}Rn)(5.46 \times 10^{-3}) = \underline{1.65 \times 10^{9} \text{ Ci } ^{222}Rn}$$

The total radon release during the million year period is, therefore

$$(1.80 \times 10^{9}) + (1.65 \times 10^{9}) = \underline{\underline{3.45 \times 10^{9} \text{ Ci } ^{222}Rn}}$$

To place these release quantities in some perspective they may be compared with the amount of ^{222}Rn which enters the atmosphere from the natural exhalation of radon from the earth. Wilkening, Clements and Stanley[1] estimate the world-wide total ^{222}Rn exhalation from the land areas of the globe to be 52 curies per second. The contributions from lava covered areas, oceans, and the ice caps of the Antarctic continent and Greenland are negligibly small. This is equal to a release rate of 4.49×10^6 Ci ^{222}Rn per day.

The natural release of ^{222}Rn during a million year period would be:

$$(52 \text{ Ci/sec})(3.15 \times 10^{7} \text{ sec/yr})(10^{6} \text{ yr}) = \underline{1.64 \times 10^{15} \text{ Ci } ^{222}Rn}$$

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[1] M. H. Wilkening, W. E. Clements, and D. Stanley, "Radon-222 Flux Measurements in Widely Separated Regions," Proc. Second International Symposium on the Natural Radiation Environment, August 7-11, 1972, Houston, Texas USA. Volume II, pp. 717-730.

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Answer (Cont'd)

Because ^{222}Rn has a short half-life, 3.82 days, all of the radon released does not accumulate in the atmosphere, most is lost by radioactive decay. An equilibrium condition is soon established where radioactive decay removes radon from the atmosphere at a rate equal to the release rate.

The maximum atmospheric inventory of ^{222}Rn may be calculated from the expression:

$$I_{max} = QC\ \tau$$

where I_{max} = maximum atmospheric inventory

QC = release rate (Ci/day)

τ (tau) = mean life = $T_{1/2}\ /\ln^2$

Mean life ^{222}Rn = 3.82 days/0.693 = 5.51 days

The maximum atmospheric inventory for natural release (4.49×10^6 Ci ^{222}Rn/day) is:

$$I_{max}\ \text{natural} = (4.49 \times 10^6\ \text{Ci}\ ^{222}\text{Rn/day})(5.51\ \text{days}) = \underline{2.47 \times 10^7\ \text{Ci}\ ^{222}\text{Rn}}$$

For comparison the maximum atmospheric inventory from the radon released from 170×10^6 MT of uranium mill tailings at the beginning of the million year period under consideration would be 248 Ci ^{222}Rn.