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Honorable John F. Ahearne
Chairman
Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Dr. Ahearne:

The information you requested on radon from Dr. David Rosenbaum, Deputy Assistant Administrator for Radiation Programs, is enclosed. Please make it available to the Appeals Board and the parties involved in the radon proceedings.

Sincerely yours,

William H. Ellett, Ph.D.
Chief, Bioeffects Analysis Branch
Criteria & Standards Division (ANR-460)
Office of Radiation Programs

5 Enclosures
Ltr dtd 10/6/80 from W. Ellett to Senator Baucus
Radiation Policy Council Decision Paper
Section 4 "Radiation Health Risk Estimates",
  EPA/8-78-013
RPC Task Force Position Paper on Radon in Structures
Ltr dtd 10/6/80 from A. Richardson to Senator Baucus

10/17...To OGC for Appropriate Action...Cpys to: Chm,Cmrs,OPE,EDO..80-1880

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Honorable Max Baucus
United States Senate
Washington, D.C. 20510

Dear Senator Baucus:

In a Memorandum to the Office of Radiation Programs' Staff, Mark Smolonsky, an investigator for your Subcommittee, asked a number of questions relating to EPA estimates of the lung cancer risks from radon exposures. Estimates of this risk for the total U.S. population are a function of the population's average lifetime exposure to radon in the home and work place and how much a given lifetime exposure increases the risk of lung cancer. Neither of these quantities are known with much accuracy, but information is accumulating which indicates the public risks from radon warrant serious attention.

A Radiation Policy Council (RPC) Task Force, which I chaired, recently examined the radon question and what the proper Federal role should be. Their report outlines what is known about how radon gets into the home environment, what average exposure levels might be, and the potential consequences. A copy of this interagency Task Force report is enclosed.

Radon exposures are usually expressed in terms of the concentration of short half-life radon daughter products, using a unit called the Working Level (WL). As outlined in the Task Force report, the amount of radon daughters in homes varies enormously depending on the ventilation, local geology and a number of other factors. Although average exposures are not well known, there is some concensus that the mean U.S. exposure is about 0.004 WL (Tables II-1 and III-1 in the RPC report). The actual amount of radon in homes could be more or less than this and one of the aims of the emerging Federal program is to get better data on national exposures.

As illustrated in Table II-2 of the RPC report, a wide range of risks have been estimated for radon exposures. These risk estimates vary by a factor of eight or more depending on the assumptions made in applying epidemiological data from occupational exposures (underground miners) to the general population. EPA has made a straightforward projection of the observed occupational risks to the general population. I must emphasize that we do not know if the general population would have a greater or smaller response than miners. This is a common feature of all radon risk estimates and is a major source of uncertainty.

Bearing this in mind, EPA has used three risk models to estimate the lung cancer risks from lifetime exposures. These estimates are documented in a 1979 EPA/ORP report "Indoor Radiation Exposure Due to Radium-226 in Florida Phosphate Lands." A copy is enclosed which outlines in some detail the various approaches we have used to estimate lifetime risks. If we assume children and adults have equal sensitivity, 0.004 WL yields a lifetime risk of about 4000 cases per million persons exposed for a lifetime, page 52 of the EPA report. (For the same population base, we would expect about 25,000 additional cases due to causes not associated with radon.) These estimates are for a stationary population having 1970 death rates with an average age at death from all causes of about 71 years, so that the average annual risk associated with radon is about 60 cases per year per million population. For a U.S. population of 240 million persons, this amounts to an estimated lung cancer death rate per year of about 14,000 cases. As pointed out in the 1979 EPA report, cited above, if exposures during childhood are 3 times more dangerous than adult exposures, the annual risk associated with radon would be increased to about 20,000 cases per year. On the otherhand, the less conservative risk model used in the 1979 report yields an average annual risk of about 7,000 cases per year in a population of 240 million.

We recognize that estimating the risks due to ionizing radiation is an uncertain business and that other investigators have made estimates of risks due to radon that are both larger and smaller than those made by EPA - Table II-2 in the RPC report illustrates this point. One of the most recent estimates is one made by the National Academy of Sciences' BEIR Committee in 1980. Although their methodology was quite different from that used by EPA, lifetime risk estimates using their model yields results that are almost identical to the EPA estimate of 14,000 cases per year given above, c.f., Table II-2 in the RPC report. Even so, we are not convinced that the risks from indoor radon are well understood. Projecting risks from occupational exposures to a general population may not be very accurate. However, in the absence of relevant data showing that risks to the general population are likely to be less, we believe current estimates of risk should be used.

The Radiation Policy Council has recently recommended that considerable Federal attention be directed at the radon problem and placed responsibility on EPA to provide leadership in a number of areas. Their September 25 decision paper concerning the indoor radon problem is enclosed. Expeditious action by EPA and other agencies is required by these RPC-approved recommendations.

I hope this letter and the enclosures provide sufficient information on how EPA risk estimates for radon were made. If you have questions, please contact me by phone at (703) 557-9380.

Sincerely yours,

/S/

William H. Ellett, Ph.D.
Chief, Bioeffects Analysis Branch
Criteria & Standards Division (ANR-460)
Office of Radiation Programs

3 Enclosures

cc: w/o Enclosures)
Mr. Mark Stevens, Office of Legislative Affairs, EPA
Mr. Mark Smolonsky -
Dr. David Rosenbaum (ANR-458)

ANR-460:W.Ellett:mwc 10-6-80 (CM#2, 1021, X79380)

9/17/80

U.S. Radiation Policy Council

Decision Paper

Recommendations for Council Action Based on Reports by Three Task Forces

Introduction

At its May, 1980 meeting the Council created task forces to examine the following issues:

1) Control of radon in inhabited structures
2) Occupational radiation exposure regulations
3) Low-level radioactive waste management
4) Preparation of a directory on current radiation protection responsibilities and activities

Task forces began work immediately on the first three issues. The first act of each Task Force was the preparation of a work plan which included a statement or restatement of the objective(s); a brief summary of the basic issue(s); a summary of Federal activities; a study design including assignments and schedule; and a plan for public involvement. These work plans were submitted to the Working Group and approved in early June, 1980. The fourth task, preparation of a directory, was not undertaken due to the unwillingness of any agency to assume the lead. It will be undertaken in the near future by the Radiation Policy Council staff if the requested FY 1981 resources are forthcoming.

Each Task Force prepared a position paper, dated August 15, which laid out the background and on-going activities, the basic issues or problems, and ways to address these issues and problems. These position papers were sent to the Working Group and summaries of each placed in the Federal Register (Vol. 45, No. 169, August 28, 1980, pp 57618-19).

After reviewing the position papers, the Working Group met and reviewed the conclusions in each paper. Many of the issues raised or solutions suggested, particularly in the occupational exposure area,

policy issues and were

incorporated in the development of issues for the long-term agenda (see item V). However, certain specific issues or solutions were identified by the Task Forces that the Working Group believes can be addressed now.

Recommendations

Based on the position papers, the Working Group recommends that the Council take the following actions.

o Radon Based on currently available information, radon and its progeny appear to be one of the major sources of radiation exposure for the general population. However, the existing data base on the levels of radon and its progeny in structures and factors affecting these levels is extremely limited. Information on the health effects is derived mainly from studies of uranium miners exposed to radon in an occupational setting. The Working Group and the Radon Task Force believe that a systematic assessment must be done before any decisions can be made on a national radon control strategy. Though numerous agencies have been involved in various radon assessment activites, the Federal effort clearly needs to be better focused. There is also a need for providing consistent advice to State and local governments as well as Federal agencies on radon control during the assessment period. Consequently, the Working Group recommends that the Council:

R 1) endorse the development of a Federal strategy to assess the prevelance and levels of radon and its progeny in inhabited structures in the United States;

R 2) request EPA prepare a monitoring and health effects assessment strategy for review by the Working Group no later than November 13 and for consideration by the Council at its December meeting;

R 3) request EPA bring to the Council, if or when the assessment indicates the need for control, a schedule for the development of health or technology based national standards, including related statutory authority;

R 4) request EPA take the lead, in the interim, in offering consistent Federal advice and guidance to State and local goverments and other Federal agencies with regard to specific situations where radon has been, or may be, identified as a potential problem;

R 5) direct the RPC staff to prepare a recommendation designating the responsibilities of Federal agencies in the area of radon assessment and control; and

R 6) request the Interagency Radiation Research Committee include in its research strategy the effects of radon at low levels.

o <u>Occupational Radiation Exposure Regulations</u> Numerous issues arise in establishing or revising regulations for occupational exposure to radiation. Since 1960 the foundation for such regulation has been the Federal guidance, initially the responsibility of the FRC and since 1970, of the EPA. Present occupational exposure regulations are based on guidance written in 1960 and now felt to be in urgent need of revision by a number of agencies. Once this current need to revise the guidance has been met, it is felt the other issues raised by the Task Force can be addressed, and in fact most of them have been incorporated in the recommended long-term agenda (item V). For the near term need, <u>the Working Group recommends</u> the Council:

OE 1) request EPA provide to the Working Group at least two weeks prior to each each Council meeting a report on the status of its

United States
Environmental Protection
Agency

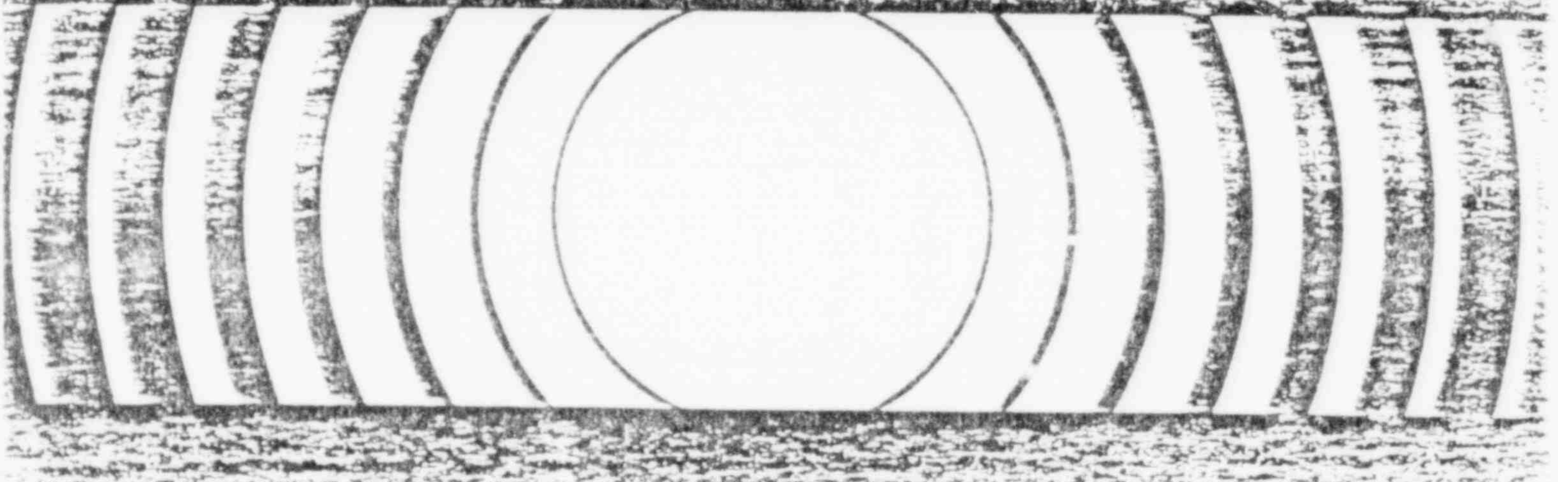
Office of
Radiation Programs
Washington DC

February 1979
EPA-520/4-78-013

Radiation

EPA

Indoor Radiation Exposure Due To Radium-226 In Florida Phosphate Lands



INDOOR RADIATION EXPOSURE
DUE TO RADIUM-226 IN
FLORIDA PHOSPHATE LANDS

Richard J. Guimond
William H. Ellett, Ph.D.
Joseph E. Fitzgerald, Jr.
Samuel T. Windham
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Revised Printing

July 1979

Criteria and Standards Division
Office of Radiation Programs
U.S. Environmental Protection Agency
Washington, D.C. 20460

PREFACE

The Office of Radiation Programs of the Environmental Protection Agency endeavors to protect public health and preserve the environment by carrying out investigative and control programs which encompass various sources of radiation. Pursuant to this goal, the Office's Criteria and Standards Division and Eastern Environmental Radiation Facility initiated a study in June 1975 to examine the radiation impact of living in structures built on phosphate lands. This study was carried out in conjunction with the Florida Department of Health and Rehabilitative Services and the Polk County Health Department. The purpose of this report is to present the findings of that study; these include estimates of the radiation levels, evaluations of the cost-effectiveness of controls, and possible actions that can be taken to reduce such levels. Readers of this report are encouraged to inform the Office of Radiation Programs of any omissions or errors. Comments or requests for further information are also invited.

We wish to express our gratitude to the staffs of the Florida Department of Rehabilitative Services and the Polk County Health Department for their cooperation and assistance. Staffs of the Eastern Environmental Radiation Facility in Montgomery, Alabama, and the Environmental Monitoring and Support Laboratory in Las Vegas, Nevada, contributed substantial efforts in sample and data analysis. We also offer our thanks to officials of the phosphate industry for their help.

William A. Mills

William A. Mills, Ph.D.
Acting Deputy Assistant Administrator
for Radiation Programs (ANR-458)

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SECTION 4.0

RADIATION HEALTH RISK ESTIMATES

4.1 THE RISK TO HEALTH DUE TO THE INHALATION OF RADON DAUGHTERS

4.1.1 The Epidemiological Data Base

The carcinogenic nature of inhaled radon and its daughter products became known through observation of fatal lung disease in some groups of underground miners. The malignant nature of their disease was recognized as early as 1879 and specifically identified as bronchiogenic cancer in 1913 (Lu71). The association between these cancers and the miners' exposure to radon was first made in 1924.

Although there has been some argument that occupational hazards other than radon may be important, extensive studies have excluded many suspected causes of excess lung cancer among underground miners such as pneumoconioses, water in the mines, heredity, fungal growths, as well as a number of metals in the ore, i.e., nickel, chromium, arsenic, and bismuth (Fr48, Hu66). Exhaust fumes from diesel engines are often mentioned as a causative factor for lung cancer among uranium miners. Yet from 1869 to 1878, well before the diesel engine was patented in 1892, lung cancer caused 75 percent of miner deaths at Schneeberg (Ha79). The observation of excess lung cancer mortality in workers in a variety of hard rock and metal mines indicates that uranium ore dust is not critical to the development of lung cancer

(Fr48, Hu66, Lu71). The only common factor identified in all miner groups studied is the presence of radon and radon-daughter aerosols in the respired air (Mi76).

The general recognition of the radon problem has resulted in a number of epidemiological studies in various countries, including the U.S.A., Canada, Czechoslovakia, Sweden, and Great Britain. Lung cancer deaths in U.S. uranium miners have been the subject of an extensive epidemiological study led by the U.S. Public Health Service (Lu71, Ar74, Ar76), which has provided much information on the etiology of radiation-induced lung disease. Nevertheless, this study and to a lesser extent other studies of cancer deaths among underground miners have limitations when used for the purpose of providing risk estimates applicable to the general population. The relative importance of these limitations has been considered in the risk estimates made below.

The estimates of the risk to miners have continued to rise as more epidemiological data have accumulated. In this regard it is of interest to compare recent information on radiogenic lung cancer with that available in 1970-1971 when the Federal guide for occupational exposure of miners was reduced from 12 to 4 Working Level Months (WLM) per year (Fe71). These guides were based almost exclusively on the experience of U.S. uranium miners exposed to high concentrations of radon daughters. At that time 70 lung cancer cases had been observed in the study group. While this number of cases exceeded the expected number of 12, about half of the cancers followed exposures of more than 1800 WLM (Lu71).

Figure 5 shows the number of lung cancer cases observed in the U.S. uranium miner study group through September 1968, and their estimated levels of exposure in WLM. The expected number of deaths depends on the number at risk at each dose level and is based on white males in the four western states where the uranium mines were in operation (Lu71). Three things are worth noting in these early results: the small number of deaths in each broadly defined exposure category, the relatively constant ratio of expected-to-observed deaths below 1800 WLM, and finally the absence of any significant difference below 120 WLM. For these reasons alone, it is easy to appreciate why early estimates of the risk due to radon inhalation were controversial; there was essentially no dose response information available. More recent data, described below, differs considerably from these 1968 results.

A fundamental limitation in this and similar investigations of lung cancer mortality is that the U.S. study is still in progress. Survivors in the U.S. study are continuing to die of lung cancer with the result that more recent data show a much larger number of lung cancer deaths than was originally projected (Na76). Another very serious limitation, peculiar to the U.S. study, is that the cumulative exposures to the 4000 workers involved were quite large, averaging

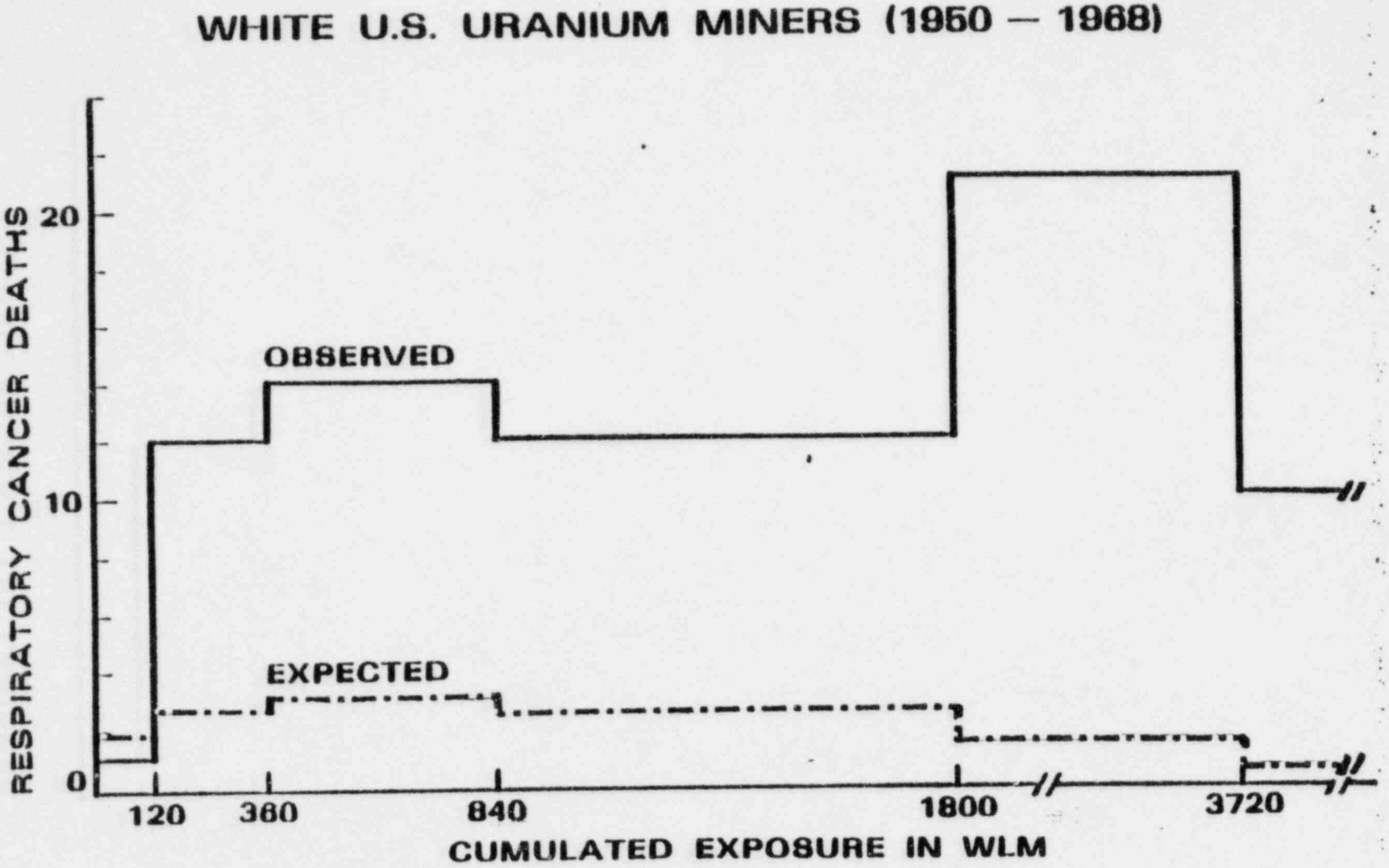

Figure 5. RESPIRATORY CANCER MORTALITY REPORTED FOR U.S. URANIUM MINERS (Lu 71). SEE TEXT FOR LIMITATIONS ON DATA

nearly 1000 WLM per miner. There is some evidence that at such high levels of exposure the risk per unit exposure is somewhat less than occurs at radon daughter exposures below a few hundred working level months (Lu71, Na76). In addition, the lung cancer mortality data for Japanese atomic bomb survivors also shows a trend for increasing lung cancer risk per unit dose at lower doses (Un77). For this reason it is advisable in risk analysis to limit the use of epidemiological data for miners to that obtained at moderate exposure levels, i.e., a few hundred working level months.

The limited information available from the study of the U.S. uranium miners can be augmented by using results derived from epidemiological studies of miner health in other countries and in other types of mining operations. The occupational environments in these mines differed substantially from those in the U.S. underground uranium mines so that the cumulative exposure from radon decay products was much smaller (Mi76, Se76, Sn74). In addition, the reported follow-up period in some of these studies is longer than for the U.S. study population. In all study groups, however, some miners are still alive and the final number of lung cancer cases is expected to be larger. The absence of data from completed lifetime follow-up studies can lead to a biased underestimation of the risk due to the inhalation of radon daughters, unless appropriate risk models are utilized which recognize that current studies have not been completed. This important topic is discussed below.

The direct proportionality of cancer risk to radon decay product exposure at levels likely to be experienced in the environment cannot be demonstrated for either human populations or by animal studies because of the large number of subjects needed. As shown below, the available data indicate that the use of a linear response curve for humans exposed to low concentrations of radon decay products is not expected to greatly overestimate or underestimate their cancer risk provided that the exposures do not exceed a few hundred working level months. Figure 6 illustrates the observed cancer excess in Canadian uranium miners who were exposed to much lower concentrations of radon decay products than are common in U.S. uranium mines, (c.f. Figure 5). Although this study may not be fully adequate to establish a quantitative estimate of the risk per working level month because data on smoking histories is incomplete, these data have been shown to be consistent with a linear dose response relationship at relatively low levels of exposure and strongly argue against a threshold dose for radiocarcinogensis in the lung (Mi76).

Figure 7 shows results obtained by J. Sevc and co-workers, from their study of uranium miners in Czechoslovakia whose mining experience started after 1948 (Se76). In that country, excess lung cancers had been observed in uranium miners exposed before World War II. An appreciation of this led to better ventilation of the uranium mines and resulted in relatively low levels of exposure to miners entering the work force after 1947. The average follow-up period in this

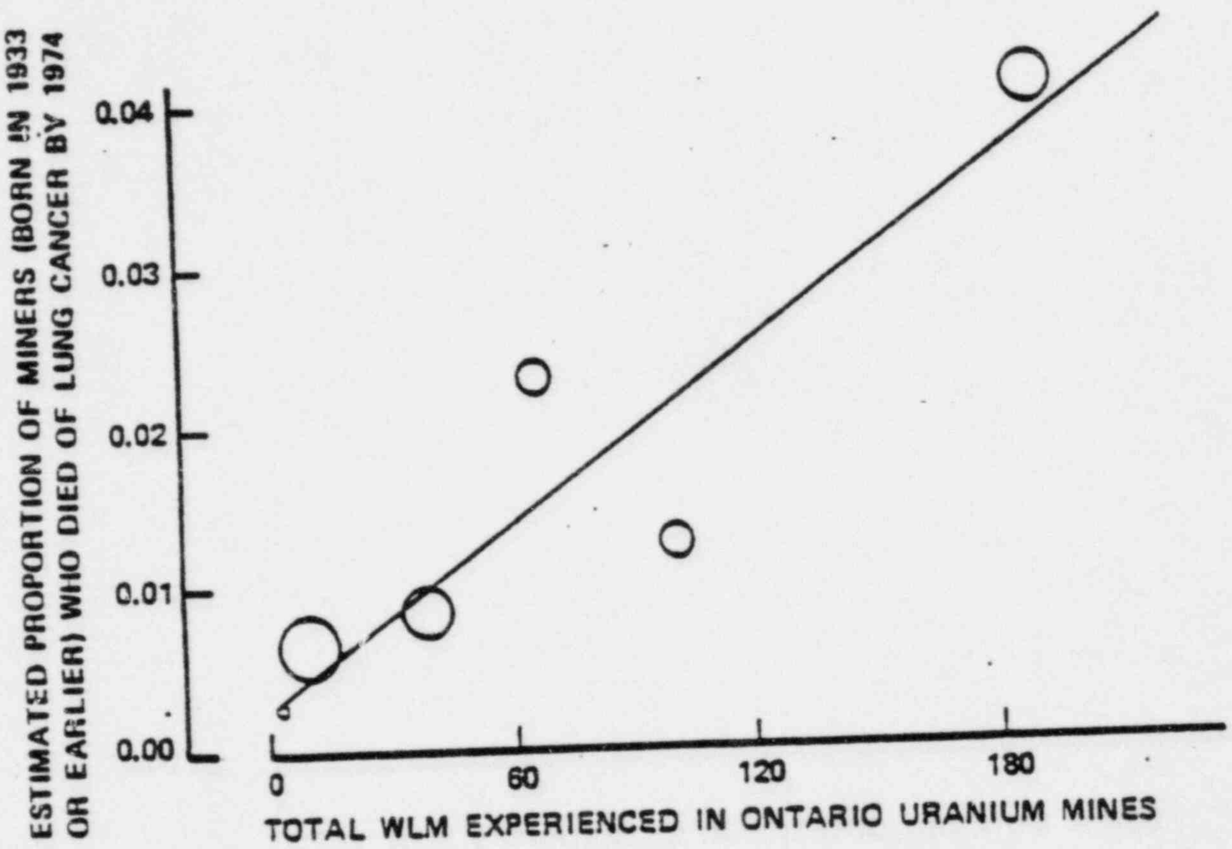

Figure 6. Respiratory Cancer Mortality in Ontario (Canada) Uranium Miners (Mi 76

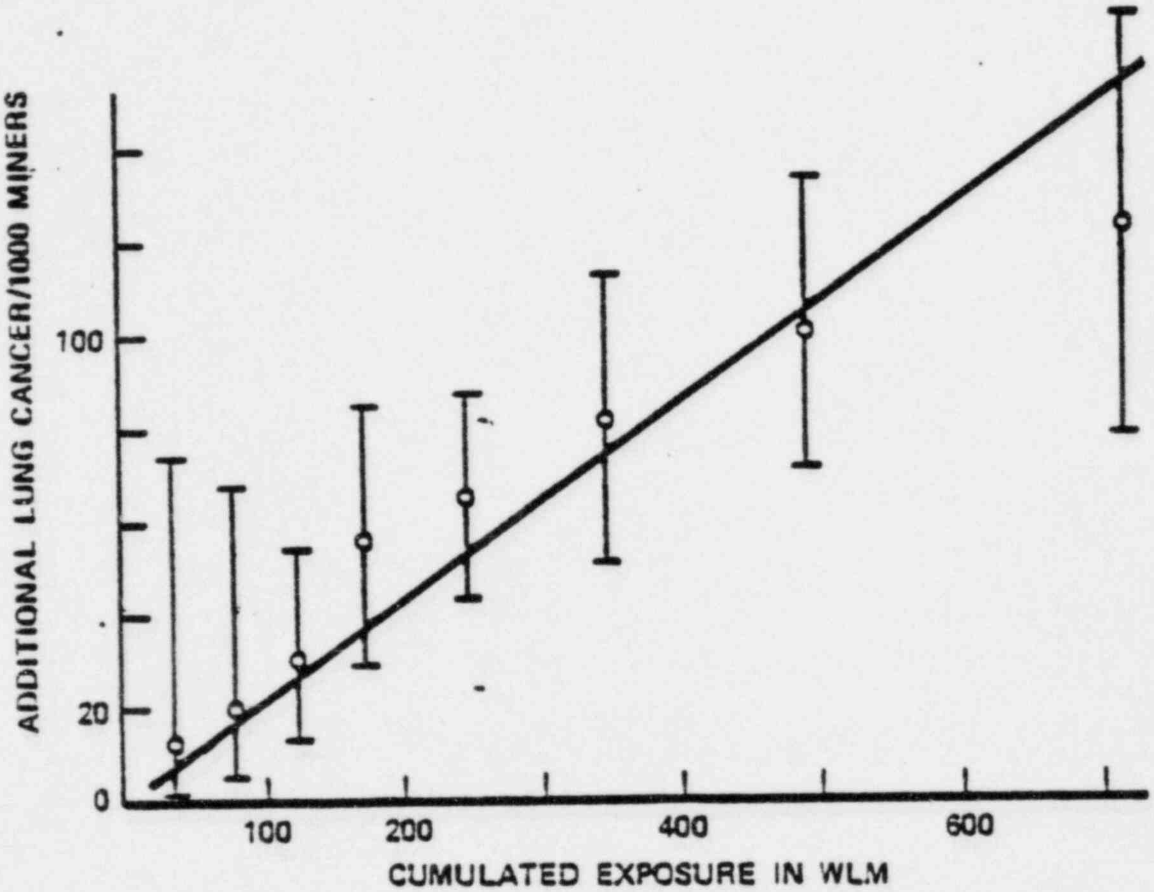

Figure 7. Respiratory Cancer Mortality Reported in Czechoslovakian Uranium Miners (1948 - 1972). Average for all Ages, (See text), (Se 76)

group is twenty three years. The high degree of correlation between exposure and excess cancer shown represents an overall average for workers of various ages. This study also found that the absolute cancer risk increased substantially with the age at which a worker entered this work force.

It should be noted also that epidemiological data of the kind illustrated in Figures 6 and 7 will always overestimate the exposure to radon decay products needed to initiate a lung cancer. The exposure considered in these studies is that accumulated throughout the working life of these miners. The dose received but ineffective in producing cancer between the period of cancer initiation and its manifestation is not discounted. For chronic exposure, the same reasoning applies to determining the minimum exposure level at which a significant number of cancers occur; an apparent threshold dose will exist, unless the cancer is initiated on the last day of exposure.

4.1.2 Risk Estimates for Underground Miners

Estimates of the cancer risk due to the inhalation of radon decay products can be made either on the basis of the dose delivered to the basal cells of the bronchial epithelium or the cumulative exposure in WLM. In 1972 the NAS-BEIR Committee used the former method to prepare their risk estimates so that other types of ionizing radiation could be considered also (Na 72). More often estimates of the risk due to radon decay products are based on the cumulative exposure in WLM (Lu71, Ar76, Na76, Un77, Mi76, Se76, Sn74).

The dose to the bronchial epithelium has been calculated by several investigators (Wa77, Ha74, Ha72). While valuable, these studies indicate that the dose (in rads) is highly dependent on a number of factors which have varying degrees of certainty. One important, but as yet poorly known, parameter is the depth below the mucosal surface at which the sites in irradiated tissues giving rise to lung cancer are located. This distance, which is likely to differ in various portions of the respiratory tract, is not known with any accuracy. In addition, no information is available on the degree of uniformity of deposited daughter products in various parts of the bronchial tree. Furthermore, the <u>in situ</u> absorption and removal pattern of the radon decay products lead-214 and bismuth-214 is poorly understood. Recent experimental evidence indicates that to postulate their complete decay in the mucus near the bronchial epithelium, as is usually done, is likely to be in error (Ja77). Because of the uncertainty in calculated doses, the Agency prefers to base estimates of the risk due to radon decay products on the cumulative exposure in working level months.

The 1972 NAS-BEIR Report used two types of analyses in estimating the radiation-induced cancer risks from follow-up studies of exposure groups (Na 72). One, called the absolute risk estimate, is the numerical increase in the number of excess cancers per unit of exposure, averaged over all age groups. The other, the relative risk estimate, is the estimated percent increase in excess cancer per unit exposure

Either of these models will yield the same number of excess cancers for a given study population if based on data from a lifetime follow-up period. Because exposed persons have been followed for a shorter duration, a choice between these models is needed. In the exposed groups studied, the risk of radiogenic lung cancer, but apparently not all cancers, increases with the participants age in about the same manner as the "natural" incidence of lung cancer, i.e., the relative risk remains constant. In contrast, the absolute risk estimates derived from the U.S. study are not constant but have continued to increase as the length of the follow-up period is increased (Na76). Lung cancer mortality among Japanese survivors has shown a similar pattern (Be77). Moreover, analysis by age shows the Czechoslovakian and Canadian lung cancer data to be grossly inconsistent with the absolute risk hypothesis (Mi76, Se76).

More recently, the Japanese cohort data on lung cancer mortality for those exposed to high LET bomb radiation at age of 50 or more have been examined for the time of occurrence of excess lung cancer after exposure (La78). Because of their age, a near lifetime follow-up study of this group is possible; the youngest surviving member was nearly 80 at the time of the study. Lung cancer mortality was compared for two dose ranges, those highly exposed, where three times the expected number of cancers was observed, and a control group receiving 0 to ten rads ("tissue kerma" in air). The time to occurrence of the lung cancers is the same for the two groups, as would be expected if the increase in lung cancer mortality follows the temporal pattern predicted by a relative risk model. This is similar to observed patterns of lung cancer observed in animals following plutonium inhalation (Na 76). In the analysis of these data as they apply to human health risks the 1976 NAS Report stated, "as already indicated, the steepness with which lung cancer death rates in the Battelle (Northwest Laboratory) beagles rose as a function of age strongly suggests that the relative risk estimate is the appropriate one to use in the present context of assessing lung cancer risk from alpha emitters." For these reasons, relative risk estimates are thought to provide a better projection of the risk of lung cancer than absolute risk estimates. However, both types are included in the set of risk estimates made below.

As an alternative to these two models, an age-dependent absolute risk model with age-dependence somewhat different from that for natural cancer incidence would also be compatible with the observations made on uranium miner populations. It should be noted that the estimated risks using such a model would be much closer to those calculated on the basis of relative risk than for an age-independent absolute risk model. As yet, parameters for age-dependent lung cancer risk models have not been published.

The estimate of the absolute risk due to exposure to radon decay products in the general environment contained in this report are based on recent mortality experience of U.S. uranium miners (Na76). Comparable U.S. data on relative risk are not available, the most recent relative risk compilation was in 1972 for the NAS-BEIR report

(Na72). Since that time, enough new cancers have occurred so that absolute risk estimates based on this group have more than doubled (Na76). The effect of this longer follow-up period on their relative risk is unknown, but may be substantial. Therefore the estimates of relative risk made here are based on studies of underground miners in Czechoslovakia and Sweden. Relative risk data for the Ontario miners have not been published. However, an oral presentation indicates the results of the Ontario study (Mi76) agree with those for Czech and Swedish miners (He78).

The percent increase in excess cancer per WLM for Czechoslovakian uranium miners is shown in Table 6. These data have been recalculated

TABLE 6

OBSERVED INCREASE IN LUNG CANCER FATALITY RATE
CZECHOSLOVAKIAN URANIUM MINERS

Mean Exposure (WLM)	% Increase per WLM
39	3.6*
80	1.0*
124	1.6
174	2.9
242	2.2
343	2.0
488	1.8
716	1.4

*Not significant at the 5% level of confidence from References Se73 and Se76 on the basis of an assumed nine-year latent period between the start of exposure and the occurrence of a radiation-induced lung cancer. At the exposure levels which occurred in the Czech uranium miners, the average risk would appear to be increased by about 2-3 percent per WLM.

Table 7 shows the percent increase per WLM observed in Swedish miners (Sn74, Ra76). In this case the increase may be as great as 4 percent per WLM at lower levels of exposure. The variations in the percent increase in lung cancer found in these epidemiological studies are not due to statistical sampling variation alone. Each study reflects differences in the age distribution of those exposed, the duration of the exposure, and the follow-up periods. Given the variations shown in Tables 6 and 7, the best that can be done is to propose a range within which the actual risk may lie, as described in Section 4.1.3.

TABLE 7

OBSERVED INCREASE IN LUNG CANCER FATALITY RATE
SWEDISH IRON AND ZINC MINERS

Mean Exposure (WLM)	% Increase per WLM
15	4*
48	4.2
218	3.3
696	2.5

*Not significant at 5% level.

4.1.3 Applicability of Underground Miner Risk Estimates to the General Population

As in most cases where the results of epidemiological studies of occupational exposures are applied to the general population, there is uncertainty in the extent of comparability between the persons at risk. Very little information is available on those non-occupationally exposed. A recent case control study by Axelson and Edling (AX79) is suggestive that the mortality per WLM for Swedish residents in homes having presumably high levels of indoor radon daughters is comparable to that observed in underground miners. However, the sample size is small and the exposure estimates too tentative to allow definite conclusions.

Since the only common factor in underground miners with increased risk of lung cancer mortality is exposure to radon and radon daughter aerosols, the comparability of mine atmospheres, indoor and outdoor, should be considered. Jacobi, _et al_., (Ja59), studied aerosol particle size distributions indoors, outdoors, and in radium mines, finding similar distributions in each place. Measurements by George (Ge75a), George, _et al_., (Ge75b) and others (Ha76, Lo77, Le75) would lead to similar conclusions. Holleman has also concluded that the difference between mine and atmospheric aerosol particle distributions was negligible, with the possible exceptions of the immediate vicinity of diesel engines and remote areas of the mine where aerosol concentrations were low (Ho68).

In general, mine atmospheres are not expected to differ greatly from environmental atmospheres of the same quality. Dusty atmospheres have low, unattached radon-daughter fractions, clean atmospheres have high unattached fractions. Well-ventilated areas have low radon-daughter ratios, poorly ventilated areas have high ratios. There is no feature which would uniquely identify either mine or environmental atmospheres, as shown in Table 8.

TABLE 8

Comparison of Typical Aerosol Characteristics

Aerosol	Ventilated Mines	Environment	
		Outdoors	Indoors
Activity Median Diameter (µm)	0.17 (a,b,c)	0.04-0.30 (e)	0.10-0.20 (a)
Concentration (particles/cm ^{3})	10^7 (drilling) (c) 10^3-10^6 (c)	10^4-10^5 (a)	10^4-10^5 (a,f)
Uncombined Fraction (Range)	0.04 (c) (0.002-0.12)	0.08 (a) (0.005-0.25)	0.07 (a) (0.003-0.20)
Radon-Daughter Ratio Range	1.0,1.0,0.4,0.3 (c) to 1.0,0.3,0.03,0.03	1.0,0.9,0.7,0.7 (a,d) to 1.0,0.8,0.5,0.3	1.0,0.8,0.8,0.7 (a,d,f) to 1.0,0.5,0.3,0.2

References:

(a) Ge75a
(b) Ge75b
(c) Ge72
(d) Ha76
(e) In73
(f) Lo77

There are several reasons for believing that the percent increase in lung cancer per unit exposure to a general population could be either more or less than that for miners. Alpha particles from radon daughters have ranges in tissue comparable to the thickness of the bronchial mucus and epithelium. The thickness of the bronchial epithelium of underground miners may be greater than is common in the general population. The BEIR Committee estimated that the shielding provided by the thicker epithelium of miners reduced their dose (and risk) per unit exposure by a factor of two compared to the general population (Na72).

On the other hand, miners' lung cancer mortality data reflect a high frequency of cigarette smoking which tends to increase their lung cancer risk relative to the general population. The degree to which smoking in conjunction with exposure to radon daughters may increase the incidence of radiation-induced lung cancer is not known. While a study of U.S. uranium miners has suggested a very strong association between cigarette smoking and radiation-induced lung cancer, the correlation between age and smoking history in this study precludes early judgment, particularly since the study also indicates that nonsmokers have a longer latent period for radiogenic lung cancers (Ar76). Some Swedish data on underground miners show that smoking may increase radiogenic cancers by a factor of about two to four (Ra76), however, these results may be dependent on the duration of follow up. Axelson and Sundell (Ax78) have reported that in a life span study of 19 exposed miners who died of lung cancer, the lifetime risk of lung cancer in non-smokers exceeded that of smokers. The latency period, however, was much shorter for smokers. A sample size this small, of course, precludes definitive judgments. Unfortunately, the Japanese data are, as yet, too incomplete to yield comparable risk estimates for cigarette smokers or non-smokers or even by sex (Be77).

Smoking is common in all populations at risk from environmental radon. While the frequency of smoking in U.S. uranium miners was not very different from that of other male industrial workers at that time, it exceeds the current level of cigarette use, particularly by females (St76). It is not clear that this will be true in the future. Cigarette smoking among younger females is continuing to increase and may approach or exceed cigarette smoking by males. If so, relative risk estimates for exposure to radon daughters based on the current incidence of lung cancer mortality, which is now almost wholly due to male deaths, will be too low. Conversely, if cigarette smoking in the U.S. becomes less common for both sexes sometime in the future the incidence of lung cancer may decrease and relative risk estimates based on the current incidence will be too high. Clearly cigarette smoking is likely to be a factor in determining the probability that a lung cancer is induced by exposure to radon daughters. The Agency recognizes that estimates of the risk due to radon daughter inhalation have a wide range and may be too high or too low, depending, among other factors, on the prevelance of cigarette smoking in the future.

Based on Tables 6 and 7 and the considerations outlined above, the range of the fractional increase in lung cancer due to radon decay products in the general environment is thought to lie between one and five percent per WLM. Studies utilizing longer follow-up times and relatively low exposures tend to support the latter figure. However, if miners are atypically sensitive to radon daughters because of other characteristics in their occupational environment the fractional increase for the general population could be as low as one percent per WLM or less.

Another characteristic of the population at risk that differs from underground miners is age. The estimated risk for miners is averaged over adult age groups only, children not being at risk. It is assumed in the absolute risk estimates given below that the risk due to radon daughters is the same for children as adults. While this has little effect on the estimates of risk made with an absolute risk model, relative risk estimates are more dependent on the assumed sensitivity of children to radiation. The Japanese experience, as reported in the 1972 BEIR Report, indicates that children irradiated at the age of nine or less have a relative risk rate of fatal solid tumors ten times that of adults (Na72). However, none of the observed cancers in this group has been lung cancer, a cancer of old age. (There is, of course, no information on lung cancer due to occupational exposure of children to radon decay products.)

The Agency believes that while it may be prudent to assume some allowance for the extra sensitivity of children, the factor adopted should be less than a factor of ten. Therefore, in the Tables below, a three-fold greater sensitivity for children is assumed in some of the relative risk calculations of mortality due to inhaled radon decay products.

Cumulative exposures for a given concentration of radon daughters differ between miners and the general public. For radon decay product exposures occurring to nonoccupationally exposed persons, consideration must be given to the fact that the breathing rate (minute-volume, etc.) of miners is greater and the number of hours exposed per month less than in the general population. Radon decay product exposures to underground miners are calculated on the basis of a working level month (defined as exposure for 170 hours to one working level). Exposure to radon daughters in the general environment occurs for an average of 730 hours per month. The breathing rate over this period of time is less than an average breathing rate appropriate for underground miners engaged in physical activity. Assuming that the average underground miner (comparatively few of whom work at the mine face) is engaged in a mixture of light and heavy activity throughout the working day, his monthly intake of air on the job is about 3×10^5 liters (In 75). An average man (reference man) is assumed to inhale 2.3×10^4 liters per day (males) or 2.1×10^4 liters per day (females) (In 75). The average intake for both sexes is 6.7×10^5 liters per month, 2.2 times more than for miners at work. Therefore, an annual exposure to 1 WL corresponds to nearly 27 WLM for exposures occurring in the general environment.

In the case of radon in residential structures, the time the residence is occupied must be considered also. On the average, Americans spend about 75 percent of their time in their place of residence (Mo76) so that about 5 x 10^5 liters of residential air is inhaled each month. This corresponds to about 20 WLM per year for a radon decay product concentration of 1 WL in residential structures. Children respire a greater volume of air relative to the mass of irradiated bronchial tissue than do adults, so that their exposure to radon daughters is almost a factor of two greater for a few years (In75). This increase has been included in the Section 4.1.4 risk estimates.

4.1.4 Risk Estimates for the General Public

Estimates of cancer risk in this report have been derived from an analysis that considers the following factors: the competing risk from causes of death other than radiation, the fractional and absolute increase in lung cancer per unit exposure, the duration of the exposure, the period between the time of exposure and the occurrence of a clinically identifiable cancer (latency), and the length of time a person is at risk following the latent period (plateau period) (Bu78). The risk estimates below assume a fixed latent period of 10 years for lung cancers (Na76). Although there may be some correlation between latency and age, relative risk estimates are not too sensitive to this parameter. Increasing the latency period to 30 years reduces the estimated risk by between 20 and 40 percent depending on the sensitivity assumed for children. In the case of lung cancer, it is assumed that following the latent period an individual remains at risk for the duration of his or her lifetime. While for some cancers a shorter plateau at risk may be appropriate, the U.S. miner data as well as the Japanese bomb survivor data reflects a continuing increase in radiogenic lung cancers beyond 70 years of age.

In these risk estimates it is assumed that the population at risk is subject to lifetime exposure and the distribution of ages is that in a stable (stationary) population (Un75). The Agency recognizes that residential dwellings are seldom occupied by one family group for their lifetimes. However, this has little effect on the ultimate health impact if another family occupies the structure. The health risk to a particular family is a function of the time they occupy the dwelling and to a lesser extent their ages. For most practical purposes, the risk due to occupancy of less than 70 years can be found by taking a fraction of the risk given below as proportional to the years of occupancy. For example, 7-year occupancy would be expected to yield one-tenth the estimated risk of lung cancer due to lifetime exposure, approximately 70 years. Residences which serve primarily as children's or geriatric's homes would be obvious exceptions.

The excess cancers due to radiation change the cause of death and the age at which death occurs in the population at risk. The EPA analysis provides estimates of the number of premature deaths, the number of years of life lost per excess death, and the total number of years of life lost by the population at risk. These parameters are included in the risk estimates presented below.

Based on the assumptions discussed above, Table 9 lists the estimated number of premature fatalities due to lung cancer that may occur in a population of 100,000 persons occupying structures having a radon decay product concentration of 0.02 WL. The total number of years of life lost by the population at risk is also tabulated. These estimates are based on relative risk models which assume a 3 percent increase in lung cancer per WLM. Two cases are compared in this Table: (1) that adults and children have the same sensitivity, and (2) that children below the age of ten are three times more sensitive than adults. It is seen that the latter assumption increases the estimated risk by about 50 percent.

Table 9

Estimated Risk of Lung Cancer Per 100,000 Exposed Individuals
Due to Lifetime Residency in Structures Having an
Average Radon Daughter Concentration of
0.02 WL Relative Risk Model*

	Excess Cancer Deaths	Total Years Lost
Child Sensitivity = Adult	2,000	30,000
Child Sensitivity = 3 x Adult	3,000	50,000

*Assumed mortality 3 percent per WLM (see text)

Table 10 presents absolute risk estimates for a radon decay product concentration of 0.02 WL and lifetime exposure. This Table has been calculated on the assumption that absolute risks are independent of the age at which exposure is received. The estimate of the number of years of life lost, compared to the relative risk for the same age sensitivity, is about the same, c.f. Tables 7 and 8. The estimated number of excess fatalities is a factor of two less than that estimated using the relative risk model. This is within the uncertainty of the relative risk estimates since the range of values for the percent increase in lung cancer per WLM is between 1 and 5 percent per WLM, <u>vis a vis</u> the 3 percent increase assumed in Table 10.

Table 10

Estimated Risk of Lung Cancer Per 100,000 Exposed Individuals
Due to Lifetime Residency in Structures Having An Average
Radon Daughter Concentration of 0.02 WL
Absolute Risk Model*

	Excess Cancer Deaths	Total Years Lost
Child Sensitivity = Adult	1,000	27,000

*The assumed risk coefficient is 10 excess lung cancer deaths per WLM for 10^6 person years at risk (Na 76).

For comparison purposes, it is of interest to estimate the number of excess lung cancers in the U.S. due to ambient levels of radon decay products in non-contaminated areas. The concentration of radon decay products in structures has not yet been surveyed extensively. Most measurements reported in the literature are for either a short duration, i.e., single samples, or in contaminated areas. An exception is the long-term radon measurement program of the Environmental Measurements Laboratory in the Department of Energy. Their measurements of radon decay products indicate average background levels in residences of 0.004 WL (Ge 78). An ambient indoor background of this level yields calculated risks one-fifth of those shown in Table 9, i.e., from about 400 to 600 cases. This is about 10 to 20 percent of the expected total national lung cancer mortality of 2900 per 100,000 in a stationary population having the 1970 U.S. mortality rates. This percentage of lung cancer mortality is not necessarily attributable to radon exposures alone, since many cofactors have been implicated in the etiology of lung cancer. It is emphasized that these risk estimates are not precise and that the actual risk from radon daughter exposures could be a factor of two or more larger or smaller.

It should also be noted that the risk estimates made here are based on a risk analysis using U.S. national health statistics. They have not been adjusted for the age, sex, or other demographic factors pertinent to persons living on phosphate lands in Florida. To the extent that the incidence of lung cancers in these areas is higher by about 40 percent than the national average, the estimated health impact of radon exposures given above may be low in Florida residents. In contrast, the persons living on phosphate lands could have demographic characteristics which differ from the national average in such a way as to lower their risks compared to those listed above. For example, if the housing were used primarily by the very old, there would be appreciably less health impact.

4.2 The Health Risk Due to External Radiation Exposure

Unlike the highly ionizing alpha particles from radon daughters, external radiation exposures are due to lightly ionizing secondary particles from interactions along the path of gamma-ray penetration. High energy gamma-rays penetrate through the body causing a relatively uniform exposure to all tissues and organs. Since all organs and tissues are exposed, the complete spectrum of cancers outlined in the

1972 NAS-BEIR Report (Na72) would be expected. In addition, some genetic risk, resulting from irradiation of the gonads, would be expected to occur.

In the case of external penetrating radiation, data presented in the 1972 NAS-BEIR Report (No 72) yields the following estimates for lifetime whole body exposure to 100,000 persons as shown in Table 11.

TABLE 11

Estimated Lifetime Risk of Excess Fatal Cancer and Genetic
Abnormalities Per 100,000 Individuals Exposed
to an Annual Dose Rate of 100 mrem

	Excess Fatal Cancers	Total Years Lost
Relative risk	470 a)	6500 a)
	150 b)	2700 b)
Absolute risk	84 a)	1900 a)
	68 b)	1700 b)

a) life time plateau b) 30 year plateau

Serious genetic abnormalities*	
1st generation	all succeeding generations
2-40	10-200

*Birthrate 2% per year

These estimates are based on the assumption that the number of health effects observed at relatively high doses and dose rates can be extrapolated linearly to the low levels of radiation usually found in the environment. Table 11 lists only fatal cancers. The 1972 NAS-BEIR Committee has estimated that a comparable number of non-fatal cancers could be induced also.

External exposure to natural background radiation in Florida, from both cosmic radiation and radiation from radioisotopes present in the soil, is about 59 millirem per year, except in regions containing anomalous sources. The estimated lifetime risk associated with this background is therefore about 60% of the values listed in Table 10.

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RPC TASK FORCE

POSITION PAPER ON RADON IN STRUCTURES

AUGUST 15, 1980

SUMMARY

Position Paper on Radon in Structures

The Task Force reviewed the physical and biological bases for concern about radon exposures to the general public and examined the status of Federal activities in four areas: epidemiological studies, regulatory authorities, programs to measure radon levels in homes, and the coordination of Federal radon research. The Task Force concluded that Council attention to this problem is warranted because of the possible prevalence of relatively large exposures, a trend toward even higher exposures due to improved energy efficiency in inhabited structures, the risk from such exposures, and the potential large population at risk.

The Task Force considered whether enough information is available to start a national program on radon control. It concluded wide ranging programs should not be undertaken until more is known about the prevalence of high exposures and ways of controling them. The thrust should be towards developing an information base that will allow good policy decisions. The Task Force also concluded that although current Federal authority cannot address some radon exposure situations, it would be premature to request additional authority until the technical basis for determining radon levels and reducing them is more fully established.

The Task Force makes five recommendations:

1. The Radiation Policy Council should take responsibility for the overall development of Federal research and policy related to the assessment and control of indoor radon exposure.

2. The Radiation Policy Council should sponsor an expert committee to evaluate and provide guidance on Federal scientific programs related to radon exposure and control. The committee's basic mission would be to provide the Council with technical evaluations and recommendations for research.

3. The Radiation Policy Council should encourage the timely acquisition and analysis of epidemiological data by Federal agencies. Moreover, the Council should request Federal agencies to make the data obtained in epidemiological studies of exposed miners and other groups available to as many analysts as possible.

4. The Radiation Policy Council should defer considering a Federal Radiation Protection Guide for indoor radon exposure.

5. The Council should prepare recommendations on the appropriate division of responsibilities between the various Federal agencies for radon control. Legislative as well as administrative approaches should be considered.

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FIGURES AND TABLES

I. Introduction

1. Statement of objective

The objective of this Task Force effort is to provide a program plan leading to a consistent national policy for the protection of the public from unduly large exposures to radon in inhabited structures.

2. Task Force activities:

May 20, 1980 - Initial Task Force Meeting

May 28, 1980 - Formulation and approval of draft Work Plan by the Task Force.

June 10, 1980 - Work Plan accepted by the RPC Working Group

June 27, 1980 - Notice of Inquiry published in the Federal Register announcing establishment of the Task Force. The Work Plan was published as part of this notice and the public was invited to comment on issues posed in the Work Plan or any additional issues relating to radon in inhabited structures.

July 17, 1980 - Task Force review of draft sections of the position paper.

August 7, 1980 - Task Force discussion of public comments, review, and revision of the draft position paper.

August 12, 1980 - Presentation of the draft position paper to the Working Group of the Radiation Policy Council.

August 15, 1980 - Submission of position paper to the Radiation Policy Council.

Drafts of the various sections of this position paper were prepared by Task Force sub-groups consisting of Task Force members and Federal resource persons. All drafts were reviewed and revised by the Task Force as a whole. Public comments are summarized in Section VI of the position paper and reproduced in Appendix III.

3. Task Force participants:

Members of the Task Force were:

William H. Ellett, U.S. Environmental Protection Agency, Chairman.

Edwin B. Shykind, U.S. Department of Commerce

Wayne M. Lowder, U.S. Department of Energy

David M. Scott, U.S. Department of Health and Human Services

James L. Christopulos, U.S. Department of Housing and Urban Development

David N. Zugschwerdt, U.S. Department of Justice

Ralph M. Wilde, U.S. Nuclear Regulatory Commission

In addition, the following scientists served as resource persons to the Task Force:

Frank E. Lundin, Bureau of Radiological Health, U.S. Department of Health and Human Services

Wayne A. Cassatt, Center for Radiation Research, National Bureau of Standards, U.S. Department of Commerce

Howard D. Ross, Office of Conservation & Solar Energy, Department of Energy

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II. Background

1. Physical and radiological characteristics of radon

Much of the radioactivity in the natural environment is due to the decay of the primordial isotopes uranium-238 and thorium-232, which have half lives of well over a billion years. These radionuclides are the generators of what are known as radioactive decay series, i.e., the decay of one radioactive atom gives rise to another radioactive atom, which in turn decays to form a third radioactive atom, etc. The uranium-238 decay series is shown in Fig. II-1. The immediate predecessor of radon-222 is radium-226, which has a 1600-year half life. All substances of natural origin contain radium to some degree. Ordinary soils and rocks contain about 1 picocurie (pCi) of radium-226 per gram, corresponding to 2.2 disintegrations per minute per gram. This is also the production rate for radon-222 atoms. Radium concentrations of a factor of ten larger or smaller than this value are not unusual under natural circumstances (UN 77). Some industrial waste materials contain concentrations ranging from 10 pCi per gram to well over 300 pCi per gram (EP 75, NR 79).

Radon-222, the immediate decay product of radium-226, is an inert gas having moderate solubility in water. Radon-222 has a 3.8-day half life, which means that radon can diffuse through dry porous soils or be

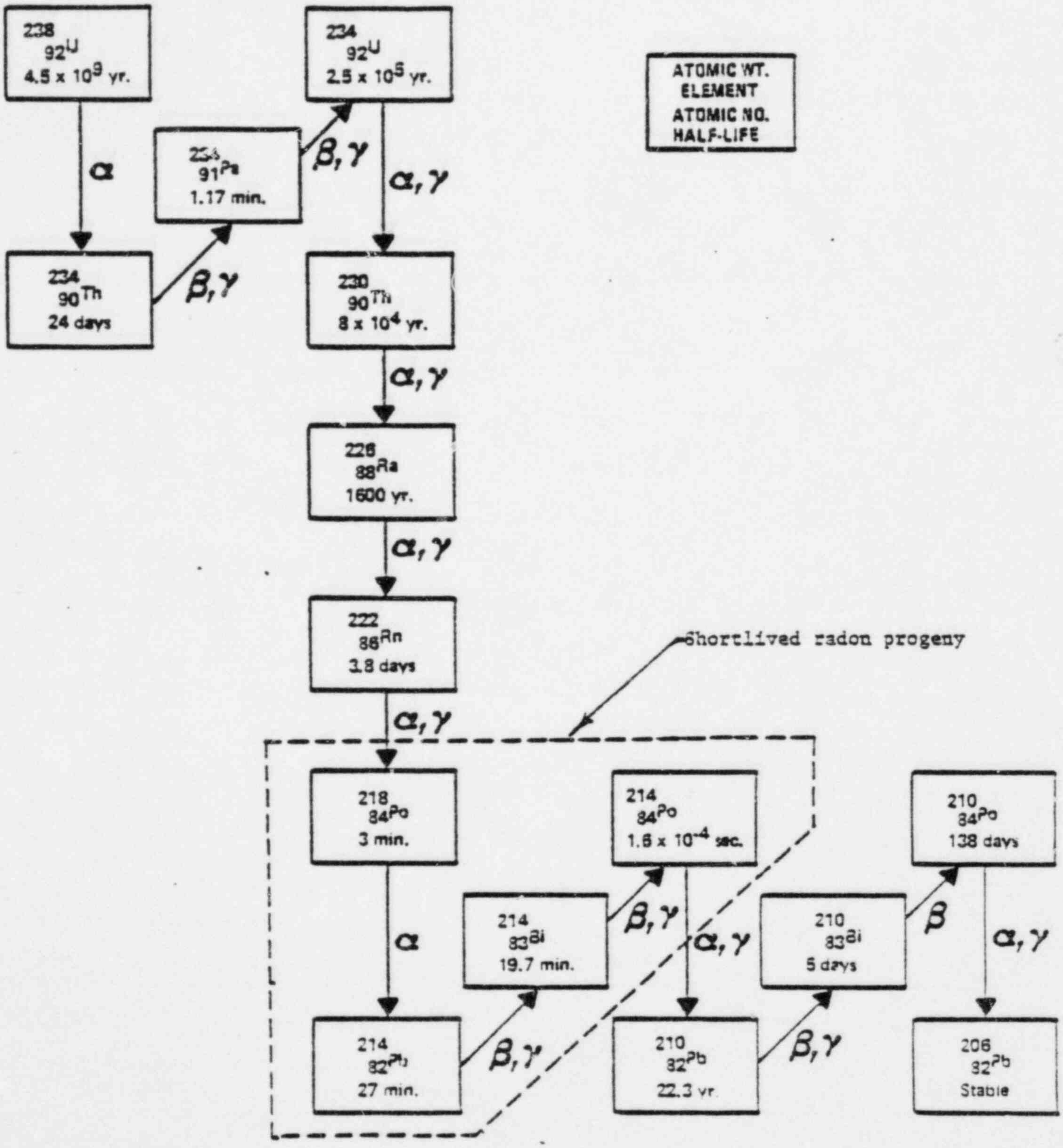

Figure II-1 The uranium-238 decay series transported in water considerable distances before it decays. Radon-220, another radon isotope formed from radium-224 in the thorium-232 decay chain, has a 55-second half life and therefore is usually a less important source of exposure to the general public than radon-222. The Task Force, therefore, has not considered it in any detail and its properties are not included in this discussion.

Radon-222 and two of its immediate progeny, polonium-213 and polonium-214, are alpha particle emitters. Unlike x-rays and the electrons they produce as secondary radiation, alpha particles are heavy doubly charged particles which produce a large number of excitations and ionizations along a very short path in tissue. For this reason, alpha particles are classified as a high LET (linear energy transfer) radiation. Because of their dense pattern of ionization they can cause more radiation damage per unit absorbed dose than x- and gamma radiation, and consequently the International Council on Radiological Protection has assigned a quality factor of 20 to alpha particle doses (IP 77). This means that for equal doses, measured in rads, the dose equivalent, in rems, attributed to alpha particles is 20 times larger than for x-rays.

Alpha particle irradiation is demonstrably carcinogenic (BA 76). Moreover, reducing the dose rate appears to have little or no effect on the amount of biological damage per unit dose that they cause (NA 76). This is thought to be due to lack of effective repair processes for alpha particle damage. At low doses the frequency of cancer from high LET radiation increases at least proportionally with dose but increases more slowly at high doses because cell killing reduces the population of the cells at risk. Moreover, for high LET particles, there is some evidence of greater cancer risk per unit dose for protracted exposures than for high dose rate acute exposures (MA 78, MU 78). The current controversy concerning reduced effects of x-rays at low doses and dose rates does not extend to radiocarcinogenesis due to alpha particles (NC 80).

A significant increase in lung cancer has been observed at cumulative occupational exposures that are comparable to those which could occur from lifetime exposure to the most highly exposed members of the general public (HE 79). The possibility of a threshold dose for lung cancer induction following alpha particle irradiation cannot be positively excluded. However, we are aware of no radiobiological or epidemiological support for a threshold for lung cancer induction due to radon progeny exposures and do not believe public policies should be based on an assumed threshold.

2. Typical exposure situations

Radon progeny exposures are measured and expressed in a specialized unit called the working level (WL) which differs from more common measures of the concentration of radioactivity in air, such as pCi per liter. Formally, a working level is any combination of the short half life radon progeny (see Fig. II-1) which ultimately emits 1.3×10^5 million electron volts (Mev) of alpha-ray energy in one liter of air. This is the amount of alpha-ray energy emitted by an equilibrium mixture of 100 pCi per liter each of polonium-218, lead-214, bismuth-214 and polonium-214. The more general definition applies to any combination of short half life radon progeny. This is convenient since the relative amount of each can change with time. The working level was originally developed as a measure of exposure to workers in uranium mines and the common unit of cumulative exposure is the working level month (WLM), i.e., occupational exposure to air containing one working level of radon progeny for 170 hours, a working month. Continuous residential exposure of a member of the general population to one working level in residential air for one year would result in about 20 WLM if it is assumed that the breathing rate is less for common indoor activities than for mining and that 75% of the time is spent indoors (EP 78).

Outside air typically has a radon progeny concentration of about one thousandth of a working level. Ambient levels are subject to rather wide variations that reflect the similar variations in the parent radon-222. Soil moisture, standing water and snow cover influence the vertical diffusion rate of radon and thus the effective dilution at ground level. Radon progeny attached to the atmospheric aerosol can also be washed out of the lower atmosphere by precipitation.

Indoors, the situation is quite different. Because there is less rapid radon dilution due to the limited exchange rate between indoor and outdoor air (typically one air change per hour in present structures), radon progeny concentrations in buildings are usually much higher than in outside air. Indoor levels vary considerably throughout the year depending on ventilation rates, particulate concentrations and many other factors. One set of data on the annual average radon progeny levels on the first floors of residential structures in uncontaminated areas shows a mean value of 0.004 WL (.08 WLM per year) with some indication that 5% of typical residences might have a concentration greater than .01 WL, (.2 WLM per year) (GZ 80). Radon progeny levels also vary with location within the structure. In the study cited above, the average concentration in basements was two times greater than in living areas. High levels of radon progeny are often found where there are high concentrations of radium in soil or in building materials. Several of the identified locations are discussed in Section III below.

It is possible that not all pathways for radon entry into structures have been properly identified, but current belief is that the most significant pathway in most cases is radon migration from soil into basements through cracks and places where piping enters. Ground water may also be a significant radon source. Many wells have substantial quantities of radon in solution even though their radium content is relatively low. Water use in the home (showers, washing machines, etc.) results in the release of radon into the home atmosphere (GES 80). This problem of elevated concentrations of radon in water is being studied extensively but its geographical extent is not well known (HES 79). A third source of indoor atmospheric contamination is the building material, where some of the radon produced by radium decay enters the pore spaces and diffuses into the room air. An occasional source of high radon in buildings is the use of reprocessed waste materials to fabricate new building materials such as gypsum board and cinder blocks. Because reprocessing of wastes is not a well-developed industrial practice in the U.S., the occurrence of such situations is probably not common. However, it has occurred in several areas (see Section III-1).

For purposes of perspective, Table II-1 indicates approximate estimates of U.S. population exposure to various sources of radiation. The exposures are given in terms of annual effective (whole-body) dose equivalent as defined by the ICRP, a quantity that can be considered as roughly proportional to overall risk (IP 77). This perspective is particularly important in the assessment of possible future trends in radiation exposure resulting from the introduction of energy conservation practices that reduce air exchange rates and from a more widespread use of radium-rich waste materials in building construction. In the former case, there can be little doubt that a significant reduction in the

Table II-1

U.S. population exposure due to various source of radiation[1]

Source	Annual Collective Effective Whole Body Dose - 10^6 person rem/y
Cosmic rays	6
Terrestrial Radiation	6
Internally deposited radionuclides	
Radon and progeny (0.004 WL)	$\simeq$ 10(2)
All others	8
Medical diagnostic x-rays	10
Fallout	≤ 1
Building materials	≤ 1
Airline travel	.1

(1) UNSCEAR - 1980 (Draft) (NA 80)

(2) Reduction of average air exchange rates in houses by one-half without additional controls would increase this collective dose to $\simeq 20 \times 10^6$ person rem/y.

average indoor-outdoor air exchange rate in U.S. housing will have a substantial impact on the radiation exposure of the U.S. population in the absence of the introduction of appropriate practical control measures. However, it appears likely that such measures can be developed as part of an overall research and development program. This perspective highlights the importance and urgency of research into the magnitude and range of present radon exposures, the effect of various environmental parameters on such exposures, noteably air exchange rates and heating and air conditioning practices, and the efficiency of possible radon control methods.

3. Estimates of health risks due to radon progeny

The short half life daughters of radon-222, (polonium-218, lead-214, bismuth-214 and polonium-214) each decay in less than 30 minutes--the first daughter, polonium-218, having a half life of just over three minutes. This is long enough for most of the charged polonium atoms to become attached to microscopic dust particles in air. Inhaled aerosols are quite small, usually less than a few tenths of a micrometer in diameter. Upon inhalation, such small particulates have a good chance of being retained on the moist epithelium lining of the bronchial tubes in the lung (IP 66). While most of such inhaled material is eventually cleared from the bronchi via mucus, this process is not fast enough to prevent exposure of the bronchial epithelium to alpha particles from polonium-218 and polonium-214. The dose delivered by these charged particles which ultimately results in cancer cannot be characterized adequately because the location of the irradiated cells that eventually give rise to lung cancer is not known with any precision.* Indeed, there is even some lack of agreement as to which cells are involved. Therefore, most estimates of the lung cancer risk due to inhaled radon progeny are in terms of a person's potential exposure to radon progeny rather than the dose absorbed in lung tissues.

There is a well-documented history of a very high incidence of lung cancer among underground miners exposed to radon progeny. Moreover, the histological type of lung cancer most frequently observed is rather uncommon in the general population. These miners were exposed to high levels of radon progeny compared to those normally occurring in the general environment. Although health studies of underground miners provide a basis for estimating risks due to radon exposures in non-occupational situations, such estimates are not hard predictions. The doses the miners received are not accurately known and the number of excess cases at a given dose level has considerable statistical uncertainty, as is shown in Figure II-2 reproduced from Archer's report AR 79. There are also uncertainties in extending these results to members of the general population because of significant physical, environmental, and demographic differences between the miners and the general public. These include possible contributions to lung cancer promotion by unidentified occupational factors and the fact that the miners were all adult males, many of whom were frequent cigarette smokers.

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*A commonly used conversion factor for the "average" dose to bronchi from a uniform deposition of radon progeny in uranium miners is 0.5 rad (10 rem) per WLM. However, the actual pattern of deposition is believed to be highly non-uniform.

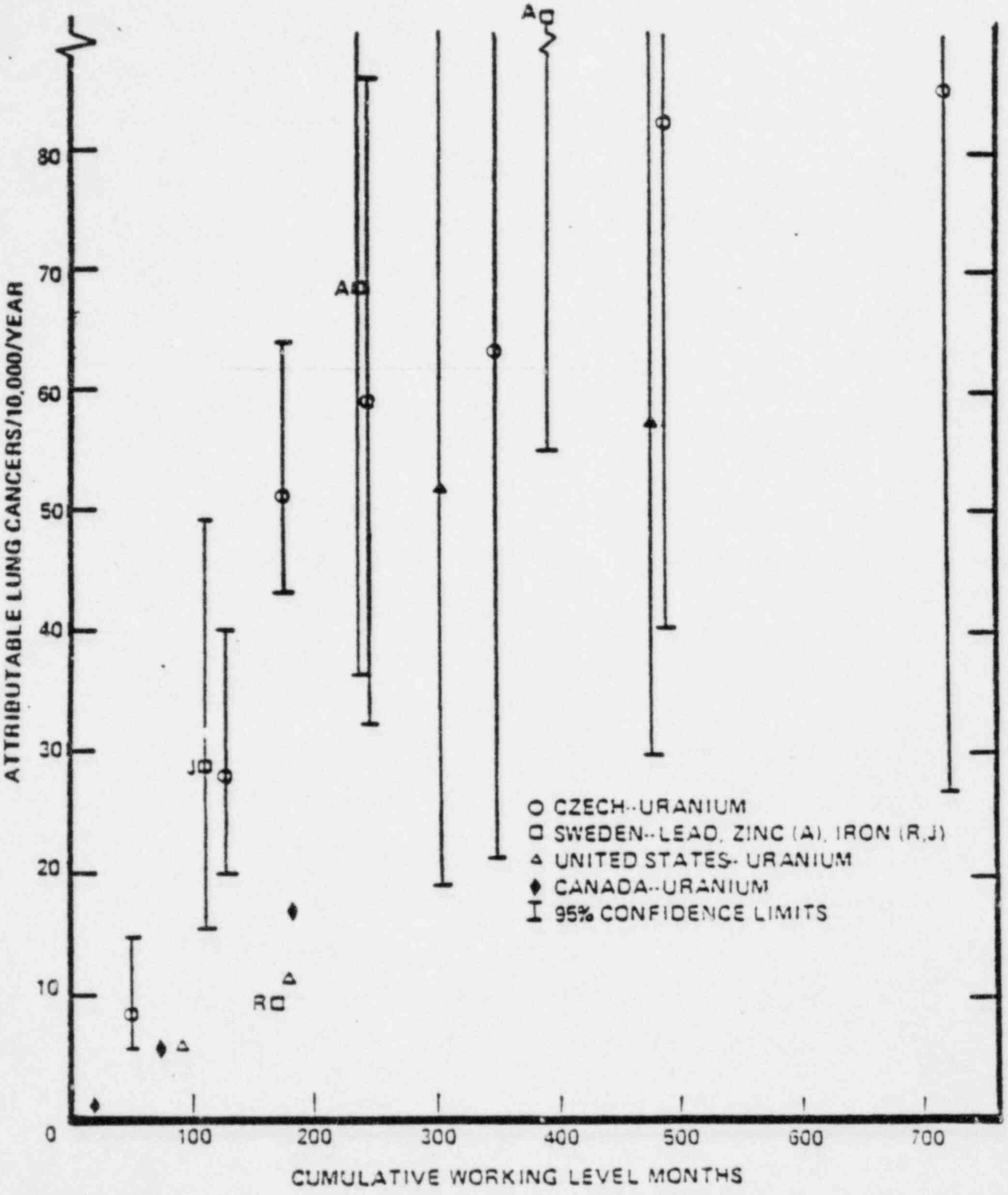

Figure II-2 Excess lung cancer in various miner groups as a function of their cumulative exposure. Note the degree of statistical uncertainty in the number of lung cancer attributable to radon daughters. (See AR 79 for full discussion).

A number of published estimates of the lung cancer risk from inhaling radon progeny were reviewed by the Task Force. All of these estimates are based on the epidemiological data from various studies of uranium and other underground miners. In addition each estimate depends on how these occupational data are applied to the general population. These risk estimates and the assumptions on which they are based are discussed briefly below.

Numerical estimates of the frequency of lung cancer due to radon progeny depend on several assumptions. These include: the shape of the dose response curve, the duration of exposure, the length of the latent period before radiogenic cancers are manifest, and the length of time following the latent period over which the cancer risk is expressed. The occupational data base for lung cancer risk includes few persons under 20 and few of the workers have been followed for their entire lifetimes. Therefore, the miner results have to be projected forward in time to estimate the effects of lifetime exposure on risk. The various <u>projection models</u> used to apply the occupational data to the general population differ considerably. Moreover, the selection of risk coefficients differ depending on which sets of miner data are considered, Fig. II-2. The net result is a considerable range in the numerical risk estimates prepared by various investigators.

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) carefully reviewed the risk experienced by underground miners in their 1977 report (UN 77). They did not develop a model to project the results of their analysis onto a general population having lifetime exposures but rather assumed a 40-year expression period for lung cancer regardless of age at exposure. The UNSCEAR risk estimate is 200-450 fatal lung cancers for 10^6 person WLM, i.e., one million persons exposed to 1 WLM at sometime in their adult life. The 40-year expression period used by UNSCEAR may not be appropriate for a general population which includes persons exposed at all ages nor does it take account of the increase in the risk of radiogenic lung cancer with advancing age, factors which are considered to varying degrees in some of the other risk estimates. Although the UNSCEAR risk estimate has the virtue of simplicity, it may not be too applicable to non-occupational exposure regimes.

Most of the other estimates of radon risk are based on lifetime exposure at a given ambient concentration of radon progeny (WL). We have expressed these other risk estimates in the units used by UNSCEAR by assuming an average lifetime exposure of 70.7 years.

The NRC published an estimate of lung cancer risk due to radon progeny in their Generic Environmental Impact Statement on Uranium Mining, (NR 79). This estimate was made by averaging the results of risk estimates for radiogenic lung cancer using the four models given in the 1972 BEIR Report and assuming a 1 WLM exposure is equal to 5 rem. The average risk for the four models was 360 per 10^6 person WLM.

EPA has published two estimates of radon risk (EP 78). One is an <u>absolute risk</u> estimate based on a risk coefficient developed by an Ad Hoc National Academy of Sciences Committee on the health effects of alpha emitting particles in the respiratory tract (NA 76). EPA applies this risk coefficient to a model population having the competing, age specific risks of death due to all causes experienced by the U.S. population in

1970, i.e., a competing risk cohort analysis (BU 78). This absolute risk model yields an estimated 350 fatal lung cancers per 10^6 person WLM. The other EPA estimate is based on a relative risk model, i.e., the percentage increase observed in exposed miners (3% per WLM) is projected across the population at risk (EP 78). Again a competing risk cohort analysis was utilized, but unlike the absolute risk model, the analysis based on relative risk takes account of how lung cancer frequency changes with age in the 1970 U.S. population. The relative risk model yields an estimated 860 lung cancer cases per 10^6 person WLM.

The National Academy of Sciences published in August 1980 the BEIR III Report which analyzes the miner data in a more detailed fashion than in previous studies (NA 80). The BEIR III model uses age dependent absolute risks. This analysis takes account of the fact that the observed lung cancer incidence in exposed miners increases with age, but only after age 35. When the new BEIR risk coefficients are applied to lifetime exposure, a competing risk cohort model yields an estimated 850 lung cancer cases per 10^6 WLM.

In response to the Radiation Policy Council's request for comments on this Task Force's work plan, the National Council on Radiation Protection and Measurements proposed a risk estimate based on a "to be published paper" by N. H. Harley and B. S. Pasternack, see Appendix III. These risk estimates are based on the risk coefficient suggested by NAS in 1976, and used by EPA in their "absolute risk" estimate, but includes two additional considerations: no cancers are expressed before age 40 and radiation damage from alpha particles is assumed to be repaired at 3.5 percent a year so that exposures occurring early in life have little effect. For lifetime exposure, this model yields 130 lung cancer deaths per 106 person WLM, substantially less than other recent estimates.

In 1979 Victor Archer, who has been principal NIOSH investigator in the U.S. epidemiology studies of uranium miners, published a review paper of the results of mine studies in both U.S. and other countries (AR 79). From this review he concluded that the risk per WLM increases as the cumulative exposure decreases so that for environmental levels of exposure the risk coefficient is 30 cases per WLM per 10^6 person years at risk. Using this risk coefficient, an EPA competing risk analysis yields 1050 fatal lung cancers per 10^6 person WLM. This is the highest risk estimate found in this review.

It should be noted that in all of these risk estimates it is assumed that children are no more harmed by radiation than adults. There is no evidence either way on this for lung cancer, a disease of old age. However, for many other cancers that normally occur earlier, the Japanese survivor data indicates children irradiated under ten years of age have a much greater relative risk than similarly exposed adults (BE 78). An EPA analysis indicates that if exposures occurring during childhood are three times more dangerous than for adults, the estimated relative risk from lifetime exposure is 50% greater than if children are no more sensitive than adults (EP 78).

Table II-2 summarizes the estimated risks from occupational radon progeny exposures outlined above. The range of these estimates is a factor of eight, which is some indication of how uncertain they are at this time. Much of this uncertainty is because the miners have not been followed for a life time and different projection models are used to predict their future mortality.

Table II-2

Estimated Life Time Risks of Fatal Lung Cancer From Radon Progeny

Estimator	Cases per 106 Person WLM	
UNSCEAR	200–450	50-year exposure to adults
NRC	360	all ages, 1967 U.S. population
EPA - absolute risk	350	cohort (stationary population)
EPA - relative risk	860	" "
BEIR III	850	" "
Victor Archer absolute risk	1050	" "
NCRP-absolute risk	130	all ages, 1975 U.S. population

Because smoking is a very important cause of lung cancer and because many of the U.S. miners studied were also frequent cigarette smokers, there is considerable interest in how smoking affects the risk due to radon progeny exposures. Early studies indicated that almost all of the excess cancers observed in U.S. uranium miners were among smokers and that the cancer causing agents had a strong synergistic (multiplicative) effect. More recent studies indicate that lung cancers took a longer time to develop in the non-smokers and that while smoking does increase risks due to radon, the difference between smokers and non-smokers is not as large as previously thought (LU 79).

A recent report by Radford and Renard (presented at the 1980 Radiation Research Society Meeting) on 1276 Swedish iron miners born between 1880 and 1919 and followed for most of their lifetime, also indicates more risks to non-smokers than previously thought. The mean cumulative lifetime exposure to these iron miners is relatively low, 85 WLM. For smokers, the observed lung cancer deaths were 2.6 times more frequent than expected for smokers in Sweden. For non-smoking miners lung cancer deaths were 8.4 times more frequent than expected for non-smokers in Sweden. Swedish smokers (who smoke less than U.S. smokers) normally have about seven times higher mortality due to lung cancer than Swedish non-smokers. So even though the non-smokers had a greater relative risk, overall they experienced a lower risk of lung cancer death. However the difference between the two groups was much smaller than has been observed in follow- up studies of younger populations.

Federal Radiation Protection Guides for the general population limit whole body doses to 500 mrem for identifiable individuals and 170 mrem per year to exposed groups where only the average dose is known. Although these guides do not apply to naturally-occurring radioactivity, they do provide some perspective on the relative risk from large radon exposures. The lifetime risk of fatal cancer associated with 170 mrem per year (whole body-lifetime exposure) are estimated as 1.2×10^{-3} to 8×10^{-3}, using 1972 BEIR Report risk coefficients and absolute and relative risk models, respectively (NA 72, EP 78). For comparison a lifetime exposure to 0.02 WL yields, using the range of estimates in Table II-2, a lifetime risk of 4×10^{-3} to 3×10^{-2}. An exposure level of 0.02 WL is five times what is thought to be the average annual value in U.S. homes; a quantity admittedly not well known. From Table III-1, described in Section III below, it appears that in at least some localities, an appreciable fraction of the population is exposed to radon progeny levels that exceed 0.02 WL.

III. Status of Federal Programs

1. Status of Federal programs to measure radon in homes

In recent years, a number of Government agencies have conducted field measurements of indoor radon. Most of these have been conducted in areas where radium contamination problems were believed to exist. Interest in indoor radon was first aroused more than 10 years ago when the use of uranium mill tailings in structures in Grand Junction, Colorado, came to national attention. More recently, EPA has studied indoor radon on phosphate lands having elevated radium concentrations. In the past few years, with an emphasis on energy conservation and "tight" building envelopes, indoor radon has become a subject of scrutiny for structures even where the only sources are common soils and building materials. Below is a summary of the major activities:

Grand Junction, Colorado: Since 1970, under a Federally-sponsored program, the Colorado Department of Health has measured indoor radon decay product levels in many hundreds of houses containing uranium mill tailings. As part of an effort to determine background levels, a number of homes in the Grand Junction area (which did not contain mill tailings) were also selected and measured for indoor radon decay products.

Florida: In 1975, the U.S. EPA began a study to assess the radiation impact on people living in structures built on phosphate land. This study was carried out in conjunction with The Florida Department of Health and Rehabilitative Services (DHRS) and the Polk County Health Department. EPA measured the indoor radon decay product levels in homes built on reclaimed phosphate land and in background homes built on unmineralized soils. Florida's DHRS and the University of Florida have conducted independent work of a similar nature.

New York City region: In 1978 the Environmental Measurements Laboratory of DOE, in an effort to determine normal environmental levels of indoor radon, conducted a program to measure indoor radon levels in a number of homes in the N.Y.C. area. Simultaneous measurements of radon decay product levels were also made. Measurements were taken in the basement and on the main floor.

Alabama: In 1978, under the guidance of State Health Departments and the U.S. EPA, the Tennessee Valley Authority measured radon decay product levels in a number of homes in Northern Alabama and neighboring states where phosphate slag was used in the house construction. A control group of houses was also measured.

San Francisco region: Recently, the Lawrence Berkeley Laboratory (LBL) began simultaneously measuring indoor radon levels and the infiltration rates of houses. The work has been done in support of DOE's house weatherization programs and energy performance standards for new buildings. In addition to houses in the San Francisco region, LBL has done similar measurements in a number of energy efficient homes throughout the country.

Montana: Two years ago, EPA and the Montana Department of Health and Environmental Sciences (MDHES) began taking indoor radiation measurements in the Butte and Anaconda areas because of the intensive local use of phosphate slag aggregate in concrete block. Very high levels of indoor radon decay levels were detected in homes with and without phosphate block. The area is highly mineralized and sits above thousands of miles of underground mine shaft. One or both of these latter factors is probably chiefly responsible for the generally elevated radon levels in this region.

Other Studies: On an ad hoc basis, numerous measurements of indoor radon levels have been performed by researchers in national laboratories and universities and by personnel in State health departments. Results of a few of these are summarized in Table III-1.

Ongoing Work: EPA has begun a study to monitor the radon levels of 1000 homes in Butte, Montana. A major goal of the study is to field validate track-etch monitors as a radon measuring device. Track-etch devices give time averaged reading of radon exposure, are inexpensive, and completely passive. If the validation of track-etch for field use is accomplished, large scale house surveys will be made possible. In another area, as part of an ongoing analysis to study the radiation impact of the phosphate slag in houses, TVA is completing the final design of a study which will measure radon decay products in 100 slag houses and 100 control houses.

Data available from these and other studies are given in Table III-1. It is important to bear in mind that a variety of measurement protocols and techniques were used in these studies so that direct comparisons are not necessarily valid. Some protocols attempt to measure the yearly average radon levels under typical living conditions, others involve single or multiple measurements over only a short period of time (generally less than a day), usually after the windows and doors have been closed for a time. The yearly average measurement is normally simulated by four or more integrated measurements over approximately one week in each of the four seasons. Even within these two categories of

Table III-1 Indoor Radon and Radon Decay Product Levels[1]

House Location	Approximate Number of Homes	Average Radon Conc (pCi/l)	Average WL	Measurement Conditions	% above .01 WL	% above .02 WL
NY/NJ - EML						
(basements)	18	2.0	.01	YR*	39%	17%
(first floors)	18	1.0	.007		17%	0%
Grand Junction, CO - CDH (background)	29	(1.1)**	.007+	YR	25%	0%
Florida						
(phosphate) - EPA&DHRS	100	(2.5)	0.015	YR	40%	25%
(background) - EPA	29	(0.5)	0.0033	YR	3%	0%
(background) - DHRS	28	(0.65)	0.004	YR	4%	0%
(background) - UF	13	0.8+	0.004+	YR	14%	14%
Butte, MT - EPA & MDHES	56	(3.3)	0.02	YR	75%	38%
Anaconda, MT - EPA & MDHES	16	(2.6)	0.013	YR	56%	25%
Alabama and Neighbor States TVA						
(phosphate slag, first floors)	5	(2.8)	0.017	Jan-May	40%	40%
(phosphate slag, basements)	17	(3.6)	0.018	Jan-May	76%	35%
(control, basements)	5	(2.8)	0.014	Jan-May	60%	40%
San Francisco Region - LBL	25	0.3	(0.002)	Grab D&W Closed++	0%	0%
Energy Efficient Homes (various locations) - LBL	17		(0.027)	Grab D&W Closed	76%	35%
Soda Springs, Idaho - IDHW (phosphate slag, basements)	100	1.4+	0.006+	Grab D&W Closed	25%	2%
Illinois - ANL (with unpaved crawl space)	22	6 houses > 10.0 pCi/l of Rn 9 houses > 5.0 pCi/l of Rn		Grab Sample D&W Closed		(41% > 0.03 WL)

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[1] Compiled by Office of Radiation Programs, U.S.E.P.A.

* YR means year round average under occupied conditions (air pump integrated measurements)

\+ Geometric mean

** Values in parenthesis are not direct measurements, but are calculated using a characteristic radon decay products/radon equilibrium ratio of 0.5 for basements and 0.61 elsewhere.

++ Doors and windows of structure were closed for a time before taking a grab sample or continuous measurement.

measurement protocols, there are important differences in the measurement process. In short, there is a great need to standardize measurement protocols and techniques to facilitate comparison of the results of future field studies. In developing these protocols and techniques, it will be important to evaluate the performance of existing measurement devices and to develop new ones where required (see following section).

2. Current status and needs for coordination of Federal research

Measurement programs, instrument development, and the development of control technology and its application are the main components of a comprehensive research program on indoor pollutants in general, and radon in particular. Although there is much work with respect to radon now underway in each of these categories, there has been a fragmentation of effort among the various agencies with somewhat differing (and sometimes unclear) responsibilities. This has been the understandable result of the fact that each agency has responded independently to problems related to its mission as they have arisen. This situation clearly points to the need for, among other things, a comprehensive interagency research program whose scale and organization are consistent with the magnitude and complexity of the potential problems and whose components are responsive to the various agency requirements. The information developed as a consequence of such a program will be an essential ingredient to basic Federal policy decisions concerning indoor radon problems.

The data that have been obtained in recent years on radon and radon progeny levels in inhabited structures are sufficiently extensive to permit a gross assessment of the possible health risks associated with current and possible future population exposures. However, as indicated in the previous section, most of this information has been developed in response to unusual exposure situations; for example, contaminated industrial sites, the re-distribution of uranium mill tailings, and construction on reclaimed phosphate land. Very little is known about the frequency distribution of individual exposures in "normal" settings and there is little quantitative understanding of how the various types of radon sources, radon transport properties, construction practices, building heating and ventilation methods, environmental parameters, and human activities affect the magnitude of the long-term exposure to radon and its decay products. A much more extensive information base needs to be developed before optimal control and regulatory strategies can be realized. This is a fundamental problem that may seriously impede policy development. This problem should be urgently addressed through the following types of research programs.

A measurement program designed to characterize the indoor radon exposure of a large population necessarily involves both large-scale surveys and detailed investigations of individual structures. The latter studies provide basic information on the various factors that influence radon exposure; information that is essential to the interpretation of the less detailed data obtained in the surveys. It will also allow forecasting of national radon exposure levels as trends towards reduced ventilation continue. The survey results define the range of normal indoor radon exposures and provide a screening mechanism for areas and/or structures deserving of further study.

Those two types of measurement programs require different types of instrumentation. For surveys, it is desirable to have a large number of low-cost and simply operated detectors that can both be handled and deployed by relatively inexperienced personnel and yield reliable data on long-term radon or radon progeny exposure. For detailed studies, an array of more sophisticated instruments is needed to accurately determine the key parameters, which might include not only radionuclide concentrations but also particle size distribution, condensation nuclei concentration, unattached fractions, air exchange rate, radon exhalation rate, temperature, pressure, humidity, etc. It appears that various techniques now in use or being developed may be at least minimally adequate for these programs, but there is need for further evaluations and improved methods. There is also a need for formal mechanisms of quality control in the measurement programs conducted by the various laboratories through the conduct of intercomparisons and intercalibrations as well as the development of common measurement protocols.

In addition to the field studies described in the previous section, a number of radon and decay product control methods have been studied. Where uranium mill tailings have been used, the primary control method is removal. However, in less extraordinary situations, sealants, ventilation and indoor particulate removal systems have been implemented with varying degrees of success. A new approach is the use of air-to-air heat exchangers on mechanical ventilation systems. This may result in improved energy conservation without the necessity for substantial reductions in air exchange rates. All of these methods are presently being investigated. Increased research on such control techniques will play an important role in the identification of appropriate (cost-effective) remedial actions that may have to be integrated into the application of energy conservation measures in inhabited structures on a large scale.

An important first step in the development of a coordinated national research plan on radon and other indoor pollutants has been taken by an ad hoc interagency task force sponsored by the Environmental Protection Agency and the Department of Energy. This group's preliminary draft report addresses the overall indoor pollution problem and the many relevant issues in sufficient detail to provide a useful starting point for the more formal efforts recommended here. It also emphasizes the need for a coherent national plan for the investigation of all pollutants of potential public health significance. The radon problem should not be considered in isolation, particularly considering the difficulties associated with carrying out large-scale field studies and the opportunities presented by such studies for multi-pollutant measurements. This developing plan is likely to include elements of direct interest to the Council including the collection of information on existing and anticipated Federal programs and the collection and assessment of available data on pollution exposure.

Another aspect of research coordination is the interaction of Federal agencies and laboratories with the State and local agencies that may be closely involved in the extensive field studies. An important potential avenue for such interaction is the Conference of Radiation Control Program Directors, which has already taken an interest in technologically enhanced natural radiation exposure. This avenue should be explored further.

3. Current status of epidemiological studies

At first sight, the number of investigations of the health status of underground miners and others exposed to radon progeny is impressive. Appendix I lists 7 U.S. studies and 10 in Canada and Europe. However, while data collection has been extensive for most of the reported studies, only rather preliminary results are available and for some none at all. In view of the long latent period before lung cancer appears, particularly for the case of non-smokers, long-term follow-up is essential.

The Japanese A-bomb survivor data indicate that for those exposed at age 50 or more, the increase in lung cancer fatalities due to radiation is not only much higher than those not exposed but also shows the same rapid increase with aging. If this same pattern holds for those exposed when they were young adults, the cancer mortality in exposed uranium miners will be much greater than has been observed to date. Therefore, lifetime follow-up of miner populations is essential. A sustained effort by the U.S. and other governments is needed to insure that all possible information is obtained from exposed groups, including those not occupationaly exposed. As yet very little effort has been directed at the latter.

4. Current regulatory authorities

There is currently no Federal legislation which might be invoked as the statutory basis for a generalized program of regulation with respect to radon exposure levels in inhabited structures. Initially, we reviewed Section 112 of the Clean Air Act, 42 U.S.C. Sec. 7412, in view of the recent EPA action in listing radionuclides as hazardous air pollutants pursuant to 42 U.S.C. Sec. 7412(b). See, EPA Federal Register Notice at 44 F.R. 76,730, et seq. (December 27, 1979). However, the thrust of Clean Air Act regulation is toward prevention of atmospheric pollution and the maintenance of ambient air quality. Neither of these terms has been treated as providing coverage of emissions into the internal air of buildings. On the contrary, the regulations implementing the Clean Air Act specifically define the term "ambient air" as "... that portion of the atmosphere, external to buildings, to which the general public has access." 40 C.F.R. Sec. 50.1(e), (Emphasis supplied).

There does exist a basis for the regulation of indoor radon exposure levels in certain limited circumstances under current Federal legislation. Specifically, certain waste materials, known to be radon sources, are subject to regulation under the Atomic Energy Act (uranium mill tailings) and the Resource Conservation and Recovery Act (e.g., wastes from uranium or phosphate mining). Typically, the use of such wastes as fill material, or the use of sites containing deposits of such wastes as building sites in the absence of appropriate disposal/reclamation techniques, will result in elevated radon levels within the structures involved.

In the case of uranium mill tailings, regulation by the Nuclear Regulatory Commission is now specifically mandated, pursuant to an amendment to the definition of the term "byproduct material" (42 U.S.C. Sec. 2014(e)) in the Atomic Energy Act accomplished by the Uranium Mill Tailings Radiation Control Act of 1978. Based on this explicit amendment the NRC is authorized, by virtue of the licensing powers granted pursuant to 42 U.S.C. Sec. 2111, to regulate the distribution or transfer of uranium mill tailings and to establish safety standards for the protection of health. The regulatory authority thus granted is all-inclusive since the possession of any "byproduct material" (defined to explicitly include uranium mill tailings) is forbidden except to the extent authorized by license.

Similarly, radon-emitting wastes from uranium or phosphate mining activity are subject to regulation as hazardous wastes pursuant to the Resource Conservation and Recovery Act of 1976 (RCRA), 42 U.S.C. Sec. 6921, <u>et seq.</u>, pursuant to the authority to list such waste and to regulate its storage and disposition so as to protect human health and the environment. As of this writing, however, EPA has deferred listing radioactive wastes under 42 U.S.C. Sec. 6921 in light of the pendency before Congress of an amendment to RCRA to temporarily suspend EPA authority to regulate radioactive wastes except as necessary to avoid unreasonable risks to human health, and the limitation of the health hazard posed by such wastes to the half dozen States in which they are generated. See, generally, Supplementary Information, Part III.A.3., EPA Notice of Final Rule, Interim Final Rule and Request for Comments Re Hazardous Waste Management System: Identification and Listing of Hazardous Waste, 45 F.R. 33,086-33,087 (May 19, 1980).

Regulation of radon in inhabited structures under either the Atomic Energy Act or the Resource Conservation and Recovery Act is limited to situations involving the utilization of material which emits radon, and otherwise meets the respective statutory definitions of "byproduct material" or "hazardous waste". A slightly more generalized regulatory basis may be found under the Toxic Substances Control Act of 1976 (TSCA), 15 U.S.C. Sec. 2601 - Sec. 2629. As is the case with the other statutory authorities referred to, however, regulation of radon under this statute would result from the regulation of chemical substances or mixtures which are radon emitters, e.g., radium. Moreover, it is clear the principal thrust of the TSCA regulatory scheme is aimed at chemical substances or mixtures subsequent to manufacturing or processing activity, an emphasis which limits its utility in regulating naturally-occurring radon. In addition, TSCA authorizes regulation to prevent an "...unreasonable risk of injury to health....", 15 U.S.C. Sec. 2605(a). This standard for triggering statutory coverage is arguably more stringent than that involved in the case of the other statutes discussed above, and may well require more vigorous evidence of adverse health effects than is currently possible. *Cf. Industrial Union Dept.* v. *American Petroleum Institute*, (S. Ct. Docket No. 78-911, decided July 2, 1980).

Under the Safe Drinking Water Act (42 U.S.C. Sec. 300f through Sec. 300j-10), EPA has authority to establish Maximum Contaminant Level (MCL) for radioactive pollutants in the finished drinking water furnished by community water systems to their customers. Private wells are unregulated (EP 76). No MCL for radon has been promulgated, although the Agency is actively considering the problem. The Agency believes that, under the authority cited above, an MCL for drinking water could be based on the radon concentration in water or the consequent indoor air concentration due to radon entrained in drinking water.

In addition to the so-called "environmental" statutes discussed above, the Department of Housing and Urban Development has authority to issue regulations to implement the national housing policy goal of, inter alia, "...a decent home and suitable living environment for every American family...." 42 U.S.C. Sec. 1441. The Department takes the view that, under this authority, it could promulgate regulations which, on a prospective basis (e.g., applicable to mortgages refinanced or entered after the effective date of such regulations), could establish radon exposure limits with respect to public housing and private housing financed in whole or in part with Federal financial assistance. With respect to farm housing, the Secretary of Agriculture is statutorily authorized to approve all building plans and specifications for new buildings and repairs for which financial assistance is authorized under 42 U.S.C. Sec. 1471, et seq. See 42 U.S.C. Sec. 1476. Despite the more specific statutory authority available to the Secretary of Agriculture, however, it is fairly certain that the regulation of radon exposure levels pursuant to 42 U.S.C. Sec. 1476 would be possible only on a prospective basis. Accordingly, while there is apparent authority, pursuant to existing legislation administered by the Secretaries of Agriculture and Housing and Urban Development, for the development of regulations concerning radon exposure levels in inhabited structures, no regulatory scheme is presently in place. Moreover, the direct impact of such regulations would be limited to Federally financed or assisted housing, a limitation which, together with prospective application, would ensure that such regulations would reach only a relatively small percentage or residential housing units and few, if any, commercial and industrial structures.

In summary, and based on the above survey, no current legislation provides any particularly useful guidance with respect to a workable approach to new legislation concerning the regulation of radon in inhabited structures. Moreover, existing limits on scientific knowledge and measurement technology may well preclude a definitive legislative resolution at this time. If this is the situation, any legislation recommended should only attempt to focus attention on the problem and seek to ensure a structured application of resources looking to future development of more definitive solutions. An example of such "bridge" legislation may be found in the Earthquake Hazards Reduction Act of 1977, codified as Chapter 86, Title 42, United States Code, 42 U.S.C. Sec. 7701-Sec. 7706, reproduced in Appendix II and discussed further in Section V.

IV. Summary of Issues

The Task Force identified four major questions in its consideration of an appropriate policy for radon control:

1. Is there adequate information to justify Council consideration of the problems arising from radon in inhabited structures?

2. Is there adequate information for starting a national program leading to the control of radon in inhabited structures?

3. Is there regulatory authority at local, State, and Federal levels to control radon exposures if necessary?

4. Is there adequate coordination of State and Federal investigations of radon exposure pathways and exposure levels?

Issue 1

Heretofore, consideration of the problem of radon in structures has been on an ad hoc basis arising from specific situations where high radon levels were identified more or less by chance. To the best of the Task Force's knowledge, it is the first governmental group to appraise the national indoor radon problem as a whole. Although this appraisal is necessarily preliminary, we believe the number of situations that have been identified are indicative of a larger national problem. "Unduly large exposures to radon in inhabited structures" are not only associated with contaminating events or other sources under man's control, but also found with considerable frequency in natural surroundings. A national survey in Canada has indicated that about 10% of their housing units may have radon progeny levels exceeding 0.02 WL. Limited studies in the U.S. suggest similar exposure patterns may exist in portions of the United States, Table III-1. Moreover, by most reckonings, the health risk due to high indoor radon levels (>0.02 WL) is considerably larger than that due to naturally-occurring gamma radiation or medical x-rays. It may also exceed the risk associated with the 170 mrem/y Federal Radiation Protection Guide for groups exposed to man-made radiation sources (See Section II-3).

Because of the possible prevalence of relatively large exposures, the likelihood of a trend toward higher exposures due to improved energy efficiency in inhabited structures, the risk from such exposures, and the potential total population at risk, which may be very large, the Task Force believes Council attention to this problem should not be deferred.

There is a need for a delineation of overall Federal and individual agency responsibilities in the development and conduct of a national action program on a continuing basis.

Issue 2

The second issue, whether or not current information is adequate for a national program, is less easily addressed. Federal control actions are being taken now on an ad hoc basis and the number of these programs is likely to increase. However, none of these actions have a potential for addressing adequately the nationwide problem. The Task Force believes that a generic study of the frequency distribution of radon exposure in structures should be made a necessary first step before Federal control actions on more than a local, problem-oriented level are contemplated. The Radiation Policy Council should provide leadership for such a State and Federal program (see Section V, below).

Even though it is clear that indoor radon exposure is likely to be a national problem, we do not believe there is sufficient information on the number and location of structures having extraordinary radon progeny levels and on the causes of such levels to make regulatory decisions. The limited sampling of structures for radon levels to date does not allow definitive generalizations concerning radon exposure. Moreover, the dynamics of radon levels in structures must be understood since it is likely that a long term trend towards higher radon levels may be in progress due to energy conservation practices. The Task Force agrees that it is likely that further investigations will show that only a sustained series of Federal and local actions can address the problem in a way that will lead to the appropriate amelioration of high radon exposure in inhabited structures. Developing a national program for regulatory control without more appreciation of its eventual scope could delay effective resolution. Such control is likely to have significant socio-economic implications that must be carefully considered prior to any action. Moreover, our present knowledge of indoor radon levels is based mainly, but not exclusively, on a biased selection of those structures most likely to be contaminated. It is possible that further study will lead to a conclusion that only a limited program of radon control is warranted. Finally, any national program involving government-mandated control of indoor radon will set a precedent for the treatment of all indoor pollutants to which the general population is exposed.

Issue 3

While the Task Force recognizes that only a portion of high radon exposure could be addressed by current regulations, it is not convinced that enforceable Federal or local standards for indoor air quality are desirable at this time. The Task Force's review of the current regulatory framework indicates that several avenues of regulation are open to public officials. Current Federal authorities relate mostly to contaminating events due to industrial programs. Contamination due to natural geological occurrences undoubtedly occur also, and in some cases, indirect control such as through HUD housing policies, see Section III-4, may be indicated. Moreover, Federal energy conservation programs and other public and private actions to save energy are likely to increase the current trend towards reduced indoor ventilation. The potential consequences of such programs cannot be ignored if their ultimate effect is to unduly increase radon exposures. However, the Task Force believes additional Federal regulatory authority should not be requested until the technical basis for determining radon levels and reducing them when necessary has been more firmly established.

Furthermore, any large scale regulatory program would require the full support of State and local officials. A long-term program, with local participation, will be needed to educate these officials and their communities on the nature of the radon problem and how it can be controlled. Again the current information base is not adequate to more than begin such an educational effort.

Issue 4

The final major issue considered by the Task Force is whether there has or has not been sufficient coordination of Federal programs concerning radon exposures. The Task Force agrees that, as good as coordination is now, it is mainly bilateral, between a single agency and a State or between two Federal agencies. As more Federal agencies and States become involved, a more formal system of coordination will have to be developed.

The main deficiency in coordinating current programs is due to their ad hoc nature. They are for the most part tied into studies of specific localities. Although local and State officials usually have a role in a particular investigation, there is no national program for helping all the States share information and solutions. Moreover, at the Federal level, interagency cooperation has been developed mostly at the field laboratory level and less in national planning and budgetary actions that take place in Washington. We do not believe all the Federal agencies are sure of what their role is or should be in defining the extent of, and participation in, a national program. While we believe regulatory legislation is not appropriate at present at either a State or Federal level, it is possible that non-regulatory legislation that establishes the role of lead agencies would be helpful. The Radiation Policy Council is well placed to coordinate a Federal program and to consider the desirability of legislative approaches. In Section V, specific recommendations and options for RPC consideration are indicated.

V. Recommendation No. 1: The Radiation Policy Council should take responsibility for the overall development of Federal research and policy related to the assessment and control of indoor radon exposure.

The Task Force agrees that a mechanism must be developed that will allow better budgetary and policy coordination of all Federal actions that touch on the indoor radon problem, and that the RPC is ideally constituted to carry out this function. It could be performed on a day-to-day basis by members of the working group representing agencies having a substantive interest in radon control. Alternately there could be a public and governmental radon policy panel composed of persons having substantial experience on radiation control philosophy who could serve on a long-term basis. Reports and recommendations would be made to the Council on a periodic basis.

There are a number of policy questions concerning radon control that are beyond the scope of decision making by scientists. For example:

- What is the appropriate balance in Federal spending for radon control compared to other public health measures?
- What is the proper balance between energy conservation and public health considerations?
- How can Federal budgeting for radon be coordinated so that large information gaps do not occur due to funding prioritizations based on each agency's immediate needs?
- How should information on radon levels in particular residential structures, on the associated risk, and on possible remedial actions be distributed to local officials, residents and the media?

The Task Force does not believe that it is an adequate source of advice on how such questions should be handled. It is of the opinion that the Council will have a continuing need for information and advice, and it believes the Working Group should make recommendations to the Council on the best mechanism.

Recommendation No. 2: <u>The Radiation Policy Council should sponsor an expert committee to evaluate and provide guidance on Federal scientific programs related to radon exposure and control</u>. The expert scientific committee should consist of Federal, State, academic and industrial scientists, to be appointed by the Council, having established reputations in radon research. This committee should have the time and scientific resources well beyond those available to the Task Force to be able to address effectively the following tasks:

1. the collection and critical evaluation of existing data on indoor radon exposures;

2. the identification of relevant ongoing and anticipated research and development programs;

3. the assessment of the present state-of-the-art in measurement methodologies

4. the assessment of the present status of control technology development;

5. the development of an interagency research plan (and/or the evaluation of existing plans), based on the results of tasks 1-4, that includes specific recommendations on needed research in the context of clearly-defined goals, and defines opportunities and possible mechanisms for coordination among the various agencies.

The Committee's basic mission would be to provide the Council with authoritative technical evaluations and recommendations for research. It could report to the Council through the Working Group, where the policy implications of the Committee recommendations on research could be considered. Specific proposals for Council action would be prepared by the Working Group.

An important aspect of the committee's work would be the identification of the scientific resources presently available for radon research. Government laboratories such as the DOE Environmental Measurements Laboratory, the EPA Eastern Environmental Radiation Facility and the EPA Las Vegas Facility have gained considerable experience in radon studies, and the same is true of research groups at DOE national laboratories and at several universities and private concerns. The expertise of the National Bureau of Standards in the standardization of measurement methodologies would also be an important resource. This multi-laboratory expertise should be utilized in the critical scientific investigations, including the detailed studies of the dynamics of radon and radon progeny in individual structures, development of new experimental and analytical methods, and the establishment of experimental protocols for large-scale studies. Such activities will provide necessary support and guidance for the survey efforts. Advantage should also be taken of the considerable experience and expertise that have been gained in other countries, notably Germany (FRG), Sweden, Britain, and Canada. Close contact should be established with the appropriate agencies and laboratories in these countries, where very similar problems are being studied and governmental action undertaken.

Alternative approaches to the development of a coordinated research program are possible, including reliance on the program plan now being developed for all indoor pollutants by the Ad Hoc Interagency Committee on Indoor Air Pollution. However, the Task Force believes that there is a compelling need for expert technical advice from the scientific community on the radon problem that can be most effectively derived through the mechanism of an Expert Committee sponsored by and reporting to the Radiation Policy Council. This Committee's activities should be closely coordinated with other Federal efforts to address indoor pollution problems.

Recommendation No. 3: The Radiation Policy Council should encourage the acquisition and analysis of epidemiological data by Federal agencies on a timely basis. Moreover, the Council should request Federal agencies to make the data obtained in epidemiological studies of exposed miners and other groups available to as many analysts as possible. Although the Federal Government has put considerable resources into data acquisition, considerably less effort has been expended on data analysis. Both Federal funding and professional expertise in this area have been in short supply. The resources needed for an improved effort are modest. Council leadership in this area could be most effective. Initiatives by the Council to encourage international cooperation in the research area are also desirable. Extensive data has been collected internationally that could contribute to the understanding of risks due to radon progeny at low doses.

The Radiation Policy Council should point out to the Interagency Radiation Research Committee that research on the potential harm from environmental radon should be encouraged and that epidemiological case control studies of non-occupationally exposed persons could be particularly useful.

Recommendation No. 4: The Radiation Policy Council should defer considering a Federal Radiation Protection Guide for indoor radon exposure. Given the serious shortcomings in our current understanding of the problem, such action would be premature. We believe that a period of several years is a more appropriate time frame for the gradual development of regulatory actions having a large potential impact at the local level. Even though Federal Radiation Protection Guides are only "advice" at the

State levels, the impact of any guide would be large since all Federal actions would have to take such a Presidential directive into account.

We think the precedents for national radon levels set by the Canadian and Swedish Governments should be carefully considered by the RPC. In Canada, government actions have been preceded by a national sampling program to determine the frequency at which high radon levels occur in both contaminated and uncontaminated areas. Subsequent remedial actions and guides are applied only to radon exposures due to industrial processes. In Sweden, the area of contemplated control is wider and the plan for eventual implementation calls for a long term and phased remedial program. As currently planned, this will eventually include building materials, sites for new construction, remedial measures in existing houses, and building specifications for new homes. The Swedish government is well aware of the impact regulations will have at the local level and their program is largely advisory at its present stage. It warrants careful study by the Working Group and Council.

Even though we do not recommend a radiation protection guide, the consequences of not having a guide for indoor radon should be appreciated by the Council. In the absence of a Federal Guide, there is a chance that the Federal agencies now advising States and other governmental agencies will give conflicting advice. In addition, some States may take independent action. We believe the Radiation Policy Council should monitor and coordinate such State and Federal activities so that if a Radiation Protection Guide for Radon is eventually developed, it will not have to be implemented on top of a set of inconsistent control levels based on ad hoc considerations. Interim guidance of a purely advisory nature could lessen the chance of this occurring. The practical advantage of interim guidance as opposed to its liability against future actions has not been considered by the Task Force. It should be addressed by a body giving policy advice to the Council, as called for in the first recommendation.

Recommendation No. 5: While the Task Force believes new regulatory authority at this time would be premature, the Radiation Policy Council should consider two possible legislative items that are not dependent on further study of the indoor radon problem.

The appropriate division of regulatory responsibilities between the various Federal agencies for radon and other indoor air pollutants is not clear and may be a subject the Congress wishes to consider in the near future. There are many technical as well as policy questions involved in such decisions and it is likely that an agreed position by the Council on this would be helpful to the Congress. Alternately, the various agencies can request legislative authority based on agency mandates; but it seems to us that such an approach circumvents the potentially very efficient mechanism for interagency coordination and cooperation implicit in the establishment of the Radiation Policy Council.

Secondly, the Council should consider the possibility of recommending legislation patterned after the Earthquake Hazards Reduction Act of 1977. This legislation does not establish Federal authority for the ameliorization of earthquake hazards. However, it does lay out a study program of these hazards under congressional mandate and provides for an adequately funded program based on Federal, State, local and private research and planning that would reduce risks. Further, it assigns various aspects of the program to specific Federal agencies, along with goals, priorities and target dates for implementation of the program. A similar legislative approach would be adaptable to the radon problem and we have included the text of the "Earthquake Hazards Reduction Act" as an appendix to this position paper. We believe it deserves serious study by both the Working Group and the Council.

VI. Summary of Public Comments

The Task Force received six letters containing comments on our Work Plan published in the Federal Register on June 27, 1980. In addition, Mr. Anthony Nero of the Lawrence Berkeley Laboratory, University of California, commented extensively on the plan at the Council public meeting in San Francisco, July 31, 1980. We have included his written presentation as part of the public comments. One or more members of the Task Force were present at each of the public hearings and briefed the Task Force on public comments pertaining to radon at our meeting on August 7, 1980.

All of the written comments received by the Task Force are reproduced in Appendix III. Albert Hazel of The Colorado Department of Health suggested that the Task Force include radon transport by drinking water in its deliberations and Gerald L. Schroeder, Arthur D. Little, Inc., suggests that source-pathway analyses would be more fruitful than direct measurements in determining concentrations of radon progeny in homes. The other commentors were more general. James Spahn, writing for the NRCP, provided the risk analysis by Harley and Pasternack referred to in Section II-3 and cautions that only annual average working level determinations provided a suitable basis for action.

Mohamed El-Ashry commenting for TVA pointed out non-residential structures were erroneously included in Table 1 of the Federal Register Notice, p. 43510, (this error is correct in Table III-1), and made other suggestions on data presentation. He also printed out the need for a slow, carefully considered national approach, a point of view also stated by Dr. Hersloff, William Geiger, and Anthony Nero in some detail. Unfortunately, Dr. Nero's comments were received too late to be fully considered by the Task Force in the development of this position paper. However, his comments warrant careful consideration by the Working Group and Council.

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BA 76 Bair, W.J. and J. M. Thomas, "Predictions of the health effects of inhaled transuranium elements from experimental animals" in Transuranium Nuclides in the Environment, IAEA, Vienna.

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APPENDIX I

EPIDEMIOLOGICAL STUDIES OF PERSONS EXPOSED TO RADON

prepared by Neal Nelson, D.V.M., Ph.D.
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Epidemiological studies of the effects of radon exposure have been carried out in a number of countries. Although several of these studies are now inactive, data analyses can be resumed at any time. They are all ongoing in the sense that substantial fractions of the populations at risk are still alive. Radon progeny exposure levels are listed as high, moderate, or low depending on whether the estimated annual exposure exceeded 12 WLM; was more than 3 WLM but less than 12 WLM; or was less than 3 WLM.

Studies in the United States

a. Uranium miners - the NIOSH laboratory in Cincinnati currently has custody of the records. After duplication of the records, part will be retained in the NIOSH Cincinnati laboratory, part will be sent to the NIOSH Morgantown laboratory.

1. Main study group, i.e., miners medically examined in 1950-1960; high level radon exposure. The NIOSH Cincinnati laboratory is updating the records and reviewing the epidemiology and effects data.

Most recent publications:

Archer, V.E., Radford, E.P., and Axelson, O. "Radon daughter cancer in man: factors in exposure-response relationships at low levels," in Conference/Workshop on Lung Cancer Epidemiology and Industrial Applications of Sputum Cytology, Colorado School of Mines Press, 1979.

Ludin, F.E., Archer, V.E., and Wagoner, J.K. "An exposure-time-response model for lung cancer mortality in uranium miners - effects of radiation exposure, age and cigarette smoking," in Energy and Health, N.E. Breslow and A.S. Whittemore, editors. Society for Industrial and Applied Mathematics, 1979.

2. Secondary study group, i.e., miners in the sputum cytology census of 1957-1968; moderate to low level radon exposure. When records are forwarded from Cincinnati, the NIOSH Morgantown laboratory plans to update these and review epidemiology and effects. (No analyses have been published.)

b. Hardrock metal miners; low level radon exposure. The NIOSH Morgantown laboratory has a review of mortality in the draft stage. The review will cover miners studied earlier (see below). The primary thrust of the review is on respiratory diseases, with little coverage of radon problems. However, a health physicist has started to review the radon measurement data so radon-related problems may be included in the final report.

Most recent publication:

Wagoner, J.K., Miller, R.W., Lundin, F.E., Fraumeni, J.F., and Haÿ, M.E. "Unusual cancer mortality among a group of underground metal miners," N.E.J.Med. 269:284-289, 1963.

c. New Mexico miners; intermediate to high level radon exposure. The University of New Mexico has started a long term mortality study of New Mexico uranium miners. The study is supported by the State and by mining companies. Only mine operator exposure data will be used in evaluating exposure levels (No publications as yet).

d. Environmental radon exposures - Colorado; low level radon exposure. A pilot study has been started to determine if there is a difference in sputum cytology or peripheral lymphocyte cytogenetics between persons living in low versus those in high levels of background radon. The Colorado State Department of Health is conducting the study for EPA..

e. "Evaluation of low level radiation effects adjacent to a uranium tailings site in Cannonsburg, PA; low level radon exposure. A pilot study investigating effects of radon and gamma radiation including peripheral lymphocyte cytogenetics, thyroid abnormalities, and lung cancer is being started by the Center for Environmental Epidemiology, University of Pittsburg; the work is being supported by EPA.

f. PHS Indian miner study; high level radon exposure. Study of the Indian miners from the main study group in Colorado, Utah, and Arizona, and from Shiprock in New Mexico. Results of the study of Navajo miners at Shiprock are to be published in 1980.

Most recent publication:

Wagoner, J.K., Archer, V.E., and Gillam, J.D. "Mortality of American Indian uranium miners," in Proceedings XI International Cancer Congress, Vol. 3. P. Bucalossi, U. Veronesi, and N. Cascinelli, editors. Excerpta Medica Amsterdam, 1975.

g. Radon in water; low level radon exposure.

1. A study of the carcinogenic impact of radon in water supplies has been started as a pilot study to identify U.S. population

groups with relatively high exposures from radon in water. If such population groups are identified, they can be studied further.

Water sources are being screened on the following basis: the sample must be from a community water supply in a community with a population of 5,000 or more and it must be an established community, i.e., with a stable population.

The study is being done by the School of Public Health, University of Texas, Houston, with NIH funding.

Most recent publication:

Gesell, T.F., Prichard, H.M., and Hess, C.T. "Epidemiological implications of radon in public water supplies," Specialist Meeting on the Assessment of Radon and Daughter Exposure and Related Biological Effects, Rome, 1980 (Proceedings to be published).

2. Maine studies - water exposures. Studies in Maine have been made correlating estimated radon concentrations in water (as a surrogate for human exposure) with cancer mortality rates by county as reported by NCI. This effort is not Federally-supported, but there is now some collaboration between the Maine investigators and the study at the Unversity of Texas mentioned above.

Most recent publication:

Hess, C.T., *et al.*, Radon-222 in Potable Water Supplies in Maine: the Geology, Hydrology, Physics and Health Effects, Project A-045-ME, Contract A-272-A, Land and Water Resources Center, University of Maine at Orono, 1979.

Studies Outside the U.S.

Canada

a. Fluorspar Miners - radon exposure may have been at high levels. Mines are now closed. Followup of miners is scheduled to continue.

Most recent publication:

Wright, E.S. and Couvers, C.M. "Radiation-induced carcinoma of the lung - the St. Lawrence tragedy," J. Thorac. Cardiovasc. Surg. 74:495-498, 1977.

b. Ontario uranium miners; low radon level exposure. The initial study is by Dr. David Hewitt (U. of Toronto). This study has been taken over by the Ministry of Labor and placed under Dr. Jan Muller. The study is to be updated and expanded.

Most recent publication:

Hewitt, D. "Biostatistical studies on Canadian uranium miners," in Conference/Workshop on Lung Cancer Epidemiology and Industrial Applications of Sputum Cytology, Colorado School of Mines Press, 1979.

c. Other; low radon level exposure. Pilot studies have been started on miners from Elliot Lake and Bancroft and employees of Denison Mines, Ltd. and Rio Algom, Ltd. So far only exposure histories have been collected. It appears that in most mines 90% of the radon exposure is at less than 120 cumulative WLM. No epidemiological data is available yet.

Most recent publication:

McCullough, R.S., Stocker, H., and Makepeace, C.E. "Pilot study on radon daughter exposures in Canada," in Conference/Workshop on Lung Cancer Epidemiology and Industrial Applications of Sputum Cytology, Colorado School of Mines Press, 1979.

England

a. Iron miners; relatively low radon level exposure.

Most recent publication:

Boyd, J.T., Doll, R., Faulds, J.S., and Leiper, J. "Cancer of the lung in iron ore (haematite) miners," Brit. J. Indust. Med. 27:97-105, 1970.

b. Other - The National Radiological Protection Board is reported to be doing a good review of radon levels in mines, particularly Cornish tin mines. There is no report of epidemiological followup being planned.

Sweden

a. Kiruna iron miners - low radon level exposures. No follow-up reported.

Most recent publication:

Jorgensen, H.S. "A study of mortality from lung cancer among miners in Kiruna, 1950-1970," Work Environm. Hlth. 10:126-133, 1973.

b. Malmberget iron miners; low radon level exposure. Mines described as having no asbestos and a gamma radiation level of 100 mr/yr. Analysis of data from miners born between 1880 and 1919 is being completed by Radford and Renard. No further follow-up is reported.

Most recent publication:

Radford, E.P. and Renard, K.G. St. Clair. "Lung cancer in Swedish iron miners exposed to low concentrations of radon daughters," in Abstracts of Papers for the 28th Annual Meeting of the Radiation Research Society, 1980.

c. Zinkgruvan lead-zinc miners - relatively low radon level exposures. No follow-up reported.

Most recent publication:

Axelson, O. and Sundell, L. "Mining, lung cancer and smoking," Scand. J. Work Environm. Hlth 4:46-52, 1978.

d. Other; background radon exposure. A study was made of lung cancer as related to estimated residential radon exposure. Lung cancer rates per WLM were estimated to be similar for these residential exposures and for mine exposures. No follow-up or expansion of the study has been reported.

Most recent publications:

Axelson, O. and Edling, C. "Health hazards from radon daughters in dwellings in Sweden," Park City Environmental Health Conference, 1979 (Proceedings in Press).

Axelson, O., Edling, C., and Kling, H. "Lung cancer and residency." A case-reference study on the possible impact of exposure to radon and its daughters in dwellings," Scand. J. Work Environ. and Health 5:10-15, 1979.

Czechoslovakia

a. Uranium miners; high radon level exposure. Studies on effects of radon exposure are continuing; however, it is not possible to check on basic data. The only material available is that which has been published.

Most recent publication:

Kunz, E., Sevc, J., and Placek, V. "Lung cancer mortality in uranium miners (methodological aspects)." Health Physics 35:579-580, 1978.

Austria

a. Spa workers and others; high and low level exposures. Studies have been made of lymphocyte cytogenetics in spa workers and townspeople at Badgastein. A dose response curve was developed but no cancer epidemiologic studies have been done yet.

Most recent publication:

Pohl-Ruling, J. and Fischer, P. "Epidemiological study on chromosome aberrations in a radon spa," Specialist Meeting on the Assessment of Radon and Daughter Exposure and Related Biological Effects, Rome, 1980 (Proceedings to be published).

APPENDIX II

CHAPTER 86—EARTHQUAKE HAZARDS REDUCTION [NEW]

§ 7701. Congressional findings

The Congress finds and declares the following:

(1) All 50 States are vulnerable to the hazards of earthquakes, and at least 39 of them are subject to a major and moderate seismic

risk, including Alaska, California, Hawaii, Illinois, Massachusetts, Missouri, Montana, Nevada, New Jersey, New York, South Carolina, Utah, and Washington. A large portion of the population of the United States lives in areas vulnerable to earthquake hazards.

(2) Earthquakes have caused, and can cause in the future, enormous loss of life, injury, destruction of property, and economic and social disruption. With respect to future earthquakes, such loss, destruction, and disruption can be substantially reduced through the development and implementation of earthquake hazards reduction measures, including (A) improved design and construction methods and practices, (B) land-use controls and redevelopment, (C) prediction techniques and early-warning systems, (D) coordinated emergency preparedness plans, and (E) public education and involvement programs.

(3) An expertly staffed and adequately financed earthquake hazards reduction program, based on Federal, State, local, and private research, planning, decisionmaking, and contributions would reduce the risk of such loss, destruction, and disruption in seismic areas by an amount far greater than the cost of such program.

(4) A well-funded seismological research program in earthquake prediction could provide data adequate for the design, of an operational system that could predict accurately the time, place, magnitude, and physical effects of earthquakes in selected areas of the United States.

(5) An operational earthquake prediction system can produce significant social, economic, legal, and political consequences.

(6) There is a scientific basis for hypothesizing that major earthquakes may be moderated, in at least some seismic areas, by application of the findings of earthquake control and seismological research.

(7) The implementation of earthquake hazards reduction measures would, as an added benefit, also reduce the risk of loss, destruction, and disruption from other natural hazards and manmade hazards, including hurricanes, tornadoes, accidents, explosions, landslides, building and structural cave-ins, and fires.

(8) Reduction of loss, destruction, and disruption from earthquakes will depend on the actions of individuals, and organizations in the private sector and governmental units at Federal, State, and local levels. The current capability to transfer knowledge and information to these sectors is insufficient. Improved mechanisms are needed to translate existing information and research findings into reasonable and usable specifications, criteria, and practices so that individuals, organizations, and governmental units may make informed decisions and take appropriate actions.

(9) Severe earthquakes are a worldwide problem. Since damaging earthquakes occur infrequently in any one nation, international cooperation is desirable for mutual learning from limited experiences.

(10) An effective Federal program in earthquake hazards reduction will require input from and review by persons outside the Federal Government expert in the sciences of earthquake hazards reduction and in the practical application of earthquake hazards reduction measures.

Pub.L. 95-124, § 2, Oct. 7, 1977, 91 Stat. 1098.

Short Title. Section 1 of Pub.L. 95-124 provided: "That this Act [enacting this chapter] may be cited as the 'Earthquake Hazards Reduction Act of 1977'."

Delegation of Functions. Functions of the President under the Earthquake Hazards Reduction Act of 1977 are delegated, transferred, or reassigned to the Director of the Federal Emergency Management Agency, see sections 1-104 and 4-204 of Ex.Ord.No. 12148, July 20, 1979, 44 F.R. 43239, set out as a note under section 2251 of Title 50, Appendix, War and National Defense.

Legislative History. For legislative history and purpose of Pub.L. 95-124, see 1977 U.S.Code Cong. and Adm.News, p. 2736.

§ 7702. Congressional statement of purpose

It is the purpose of the Congress in this chapter to reduce the risks of life and property from future earthquakes in the United States through the establishment and maintenance of an effective earthquake hazards reduction program.

Pub.L. 95-124, § 2, Oct. 7, 1977, 91 Stat. 1099.

Legislative History. For legislative history and purpose of Pub.L. 95-124, see 1977 U.S.Code Cong. and Adm.News, p. 2785.

§ 7703. Definitions

As used in this chapter, unless the context otherwise requires:

(1) The term "includes" and variants thereof should be read as if the phrase "but is not limited to" were also set forth.

(2) The term "program" means the earthquake hazards reduction program established under section 7704 of this title.

(3) The term "seismic" and variants thereof mean having to do with, or caused by earthquakes.

(4) The term "State" means each of the States of the United States, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, Guam, American Samoa, the Commonwealth of the Mariana Islands, and any other territory or possession of the United States.

(5) The term "United States" means, when used in a geographical sense, all of the States as defined in paragraph (4) of this section.

Pub.L. 95-124, § 4, Oct. 7, 1977, 91 Stat. 1099.

Legislative History. For legislative history and purpose of Pub.L. 95-124, see 1977 U.S.Code Cong. and Adm.News, p. 2785.

§ 7704. National earthquake hazards reduction program

Establishment

(a) The President shall establish and maintain, in accordance with the provisions and policy of this chapter, a coordinated earthquake hazards reduction program, which shall—

(1) be designed and administered to achieve the objectives set forth in subsection (c) of this section;

(2) involve, where appropriate, each of the agencies listed in subsection (d) of this section; and

(3) include each of the elements described in subsection (e) of this section, the implementation plan described in subsection (f) of this section, and the assistance to the States specified in subsection (g) of this section.

Duties of the President: designation of entity for development of plan; submittal of plan to congressional committees; and designation of entity for development and implementation of program, cooperation and coordination with and assistance to governmental entities of the States, and program staffing

(b) The President shall—

(1) within 30 days after October 7, 1977, designate the Federal department, agency, or entity responsible for the development of the implementation plan described in subsection (f) of this section;

(2) within 210 days after October 7, 1977, submit to the appropriate authorizing committees of the Congress the implementation plan described in subsection (f) of this section; and

(3) by rule, within 300 days after October 7, 1977—

(A) designate the Federal department, agency, or interagency group which shall have primary responsibility for the development and implementation of the earthquake hazards reduction program;

(B) assign and specify the role and responsibility of each appropriate Federal department, agency, and entity with respect to each object and element of the program;

(C) establish goals, priorities, and target dates for implementation of the program;

(D) provide a method for cooperation and coordination with, and assistance (to the extent of available resources) to, interested governmental entities in all States, particularly those containing areas of high or moderate seismic risk; and

(E) provide for qualified staffing for the program and its components.

Objectives of the program

(c) The objectives of the earthquake hazards reduction program shall include—

Earthquake resistant construction

(1) the development of technologically and economically feasible design and construction methods and procedures to make new and existing structures, in areas of seismic risk, earthquake resistant, giving priority to the development of such methods and procedures for nuclear power generating plants, dams, hospitals, schools, public utilities, public safety structures, high occupancy buildings, and other structures which are especially needed in time of disaster;

Earthquake prediction

(2) the implementation in all areas of high or moderate seismic risk, of a system (including personnel, technology, and procedures) for predicting damaging earthquakes and for identifying, evaluating, and accurately characterizing seismic hazards;

Model codes

(3) the development, publication, and promotion, in conjunction with State and local officials and professional organizations, of model codes and other means to coordinate information about seismic risk with land-use policy decisions and building activity;

Earthquake-related issues understanding

(4) the development, in areas of seismic risk, of improved understanding of, and capability with respect to, earthquake-related issues, including methods of controlling the risks from earthquakes, planning to prevent such risks, disseminating warnings of earthquakes, organizing emergency services, and planning for reconstruction and redevelopment after an earthquake;

Education of the public

(5) the education of the public, including State and local officials, as to earthquake phenomena, the identification of locations and structures which are especially susceptible to earthquake damage, ways to reduce the adverse consequences of an earthquake, and related matters;

Research respecting mitigation of earthquake hazards, the varied consequences of earthquake prediction, and assurance of availability of earthquake insurance

(6) the development of research on—

(A) ways to increase the use of existing scientific and engineering knowledge to mitigate earthquake hazards;

(B) the social, economic, legal, and political consequences of earthquake prediction; and

(C) ways to assure the availability of earthquake insurance or some functional substitute; and

Basic and applied research for control or alteration of seismic phenomena

(7) the development of basic and applied research leading to a better understanding of the control or alteration of seismic phenomena.

Federal participation

(d) In assigning the role and responsibility of Federal departments, agencies, and entities under subsection (b)(3)(B) of this section, the President shall, where appropriate, include the United States Geological Survey, the National Science Foundation, the Department of Defense, the Department of Housing and Urban Development, the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, the National Bureau of Standards, the Energy Research and Development Administration, the Nuclear Regulatory Commission, and the National Fire Prevention and Control Administration.

Research elements

(e) The research elements of the program shall include—

(1) research into the basic causes and mechanisms of earthquakes;

(2) development of methods to predict the time, place, and magnitude of future earthquakes;

(3) development of an understanding of the circumstances in which earthquakes might be artificially induced by the injection of fluids in deep wells, by the impoundment of reservoirs, or by other means;

(4) evaluation of methods that may lead to the development of a capability to modify or control earthquakes in certain regions;

(5) development of information and guidelines for zoning land in light of seismic risk in all parts of the United States and preparation of seismic risk analyses useful for emergency planning and community preparedness;

(6) development of techniques for the delineation and evaluation of the political effects of earthquakes, and their application on a regional basis;

(7) development of methods for planning, design, construction, rehabilitation, and utilization of manmade works so as to effectively resist the hazards imposed by earthquakes;

(8) exploration of possible social and economic adjustments that could be made to reduce earthquake vulnerability and to exploit effectively existing and developing earthquake mitigation techniques; and

(9) studies of foreign experience with all aspects of earthquakes.

Implementation plan; year-by-year targets; Federal and non-Federal roles; specific provisions; report to congressional committees; explanation of reasons for nonutilization of contemplated or proposed specific action

(f) The President shall develop, through the Federal agency, department, or entity designated under subsection (b)(1) of this section, an implementation plan which shall set year-by-year targets through at least 1980, and shall specify the roles for Federal agencies, and recommended appropriate roles for State and local units of government, individuals, and private organizations, in carrying out the implementation plan. The plan shall provide for—

(1) the development of measures to be taken with respect to preparing for earthquakes, evaluation of prediction techniques and actual predictions of earthquakes, warning the residents of an area that an earthquake may occur, and ensuring that a comprehensive response is made to the occurrence of an earthquake;

(2) the development of ways for State, county, local, and regional governmental units to use existing and developing knowledge about the regional and local variations of seismic risk in making their land use decisions;

(3) the development and promulgation of specifications, building standards, design criteria, and construction practices to achieve appropriate earthquake resistance for new and existing structures;

(4) an examination of alternative provisions and requirements for reducing earthquake hazards through Federal and federally financed construction, loans, loan guarantees, and licenses;

authorizations set forth in subsections (b) and (c) of this section), not to exceed $1,000,000 for the fiscal year ending September 30, 1978, not to exceed $2,000,000 for the fiscal year ending September 30, 1979, and not to exceed $2,000,000 for the fiscal year ending September 30, 1980.

Geological Survey

(b) There are authorized to be appropriated to the Secretary of the Interior for purposes for carrying out, through the Director of the United States Geological Survey, the responsibilities that may be assigned to the Director under this chapter not to exceed $27,500,000 for the fiscal year ending September 30, 1978; not to exceed $35,000,000 for the fiscal year ending September 30, 1979; and not to exceed $40,000,000 for the fiscal year ending September 30, 1980.

National Science Foundation

(c) To enable the Foundation to carry out responsibilities that may be assigned to it under this chapter, there are authorized to be appropriated to the Foundation not to exceed $27,500,000 for the fiscal year ending September 30, 1978; not to exceed $35,000,000 for the fiscal year ending September 30, 1979; and not to exceed $40,000,000 for the fiscal year ending September 30, 1980.

Pub.L. 95–124, § 7, Oct. 7, 1977, 91 Stat. 1102.

Legislative History. For legislative history and purpose of Pub.L. 95–124, see 1977 U.S.Code Cong. and Adm.News, p. 2785.

(5) the determination of the appropriate role for insurance, loan programs, and public and private relief efforts in moderating the impact of earthquakes; and

(6) dissemination, on a timely basis, of—

(A) instrument-derived data of interest to other researchers;

(B) design and analysis data and procedures of interest to the design professions and to the construction industry; and

(C) other information and knowledge of interest to the public to reduce vulnerability to earthquake hazards.

When the implementation plan developed by the President under this section contemplates or proposes specific action to be taken by any Federal agency, department, or entity, and, at the end of the 10-day period beginning on the date the President submits such plan to the appropriate authorizing committees of the Congress any such action has not been initiated, the President shall file with such committees a report explaining, in detail, the reasons why such action has not been initiated.

State assistance

(g) In making assistance available to the States under the Disaster Relief Act of 1974, the President may make such assistance available to further the purposes of this chapter, including making available to the States the results of research and other activities conducted under this chapter.

Non-Federal participation; program plan review; report to Congress; evaluation of non-Federal and Federal prediction activities

(h) In carrying out the provisions of this section, the President shall provide an opportunity for participation by the appropriate representatives of State and local governments, and by the public, including representatives of business and industry, the design professions, and the research community, in the formulation and implementation of the program.

Such non-Federal participation shall include periodic review of the program plan, considered in its entirety, by an assembled and adequately staffed group of such representatives. Any comments on the program upon which such group agrees shall be reported to the Congress.

Measures developed pursuant to subsection (f)(1) of this section for the evaluation of prediction techniques and actual predictions of earthquakes shall provide for adequate non-Federal participation. To the extent that such measures include evaluation by Federal employees of non-Federal prediction activities, such measures shall also include evaluation by persons not in full-time Federal employment of Federal prediction activities.

Pub.L. 95–124, § 5, Oct. 7, 1977, 91 Stat. 1099.

Legislative History. For legislative history and purpose of Pub.L. 95–124, see 1977 U.S.Code Cong. and Adm.News, p. 2785.

§ 7705. Annual report to Congressional committees

The President shall, within ninety days after the end of each fiscal year, submit an annual report to the appropriate authorizing committees in the Congress describing the status of the program, and describing and evaluating progress achieved during the preceding fiscal year in reducing the risks of earthquake hazards. Each such report shall include any recommendations for legislative and other action the President deems necessary and appropriate.

Pub.L. 95–124, § 6, Oct. 7, 1977, 91 Stat. 1102.

Legislative History. For legislative history and purpose of Pub.L. 95–124, see 1977 U.S.Code Cong. and Adm.News, p. 2785.

§ 7706. Authorization of appropriations

General authorization for the program

(a) There are authorized to be appropriated to the President to carry out the provisions of sections 7704 and 7705 of this title (in addition to any authorizations for similar purposes included in other Acts and the

APPENDIX III

PUBLIC COMMENTS

Arthur D. Little, Inc. ACORN PARK · CAMBRIDGE, MA 02140 · (617) 864-5770 · TELEX 921436

July 2, 1980

William H. Ellett, PhD
Task Force Chairman
Office of Radiation Programs
ANR-460
U.S. EPA
Washington, DC 20460

Dear Dr. Ellett: 4212

In response to the request for comments on issues posed by the work plan for radon control in inhabited structures, I submit the following.

There is a basic need to develop a system of measurements which, in a reasonably short period of time (perhaps one day's effort), will characterize the radon-radon daughter product (WL) "hazard potential" of an existing dwelling, a planned construction site, or of larger geographically similar regions. Knowing this potential would enable remedial measured or special construction techniques (e.g., incorporating vapor barriers into construction materials at sites of high radon flux; avoiding passing cables through subgrade walls) to be applied in order to reduce the potential radon-related radiation hazard to an acceptable level.

Measuring radon or WL a few times within a dwelling is probably inadequate for such characterization. Precipitation, changing barometric pressure, wind magnitude and direction, current depth of the water table all can affect the flux of radon into a dwelling. These variations are compounded by phenomena within the dwelling itself, such as aerosol distribution, ventilation rate and water usage.

Based on experience which my colleagues and I have had over the past 20 years in parallel fields of environmental radon-WL measurement and control, I believe that it is possible to characterize the potential radon burden of a planned or existing dwelling by quantitatively identifying the <u>sources</u> of radon at the site and the <u>pathways</u> via which the radon can move, by diffusion and/or convection, from the source into the dwelling. This can be done by quantifying; radon concentrations and radon concentration gradients within the surface

received 7/8/80

CAMBRIDGE, MASSACHUSETTS
ATHENS BRUSSELS LONDON MADRID PARIS RIO DE JANEIRO SAN FRANCISCO SÃO PAULO TOKYO TORONTO WASHINGTON WIESBADEN

two meters of soil or rock at the site; supported and unsupported radon concentrations in water (and possibly cooking gas) used in the dwelling; the general radon characteristics (emanating ^{226}Ra content, permeability) of the construction material, especially basement construction; general construction plan, especially approximate planned ventilation rate and whether the basement has drainage sumps or cables and pipes passing through subgrade walls; if forced hot air is used for heating, whether there is an air intake in the basement. These data do not require integrating results over long periods of time in order to experience a wide range of climatological and occupant-induced conditions, as is required if radon characterization is to be based on in-the-dwelling radon and WL measurements. Rather, by concentrating the effort on quantifying the <u>sources</u> and <u>pathways</u> of radon, the potential burden can be estimated in a relatively short period.

The many years of hands-on experience that we have had at Arthur D. Little, Inc., in development and evaluation of instrumentation systems to monitor radon and WL and design of systems to control and remove radon and/or radon daughter products from confined atmospheres makes us confident that the above approach has merit.

I would be happy to meet with you to discuss the above.

Sincerely,

Gerald Schroeder

Gerald L. Schroeder

GLS:rhw
Enc.

July 9, 1980

Dr. William H. Ellett
Task Force Chairman
Office of Radiation Programs
ANR-460
U.S. Environmental Protection
 Agency
Washington, D.C. 20460

Dear Dr. Ellett:

I do not believe that a national program to control radon exposures from naturally occurring high concentrations of radium and a governmental Task Force to study such levels warrant the taxpayers' money. For a governmental agency to set up such a Task Force only adds to the irresponsible sensationalism surrounding exaggerated radiation risks. Will such controls end with radon gas or will there be subsequent "Task Forces" to investigate and set limits on the number of air hours a person spends traveling, the elevation at which people live, or the number of hours a person watches color television? An increase in all of these will result in increased radiation exposure.

As may be implied by reference to reduced ventilation rates, the reduction in radon gas in inhabited structures will rely on decreased insulation resulting in higher energy costs. With rising costs of heating, the people with the least social or political means will be the hardest hit. Finally, with a program to control radon exposures in homes, there will be an additional cost either directly by the consumer of new homes or by owners of those homes requiring remedial action or through increased taxes.

It was stated in the Notice of Inquiry that "--there is apparently no Federal authority for mandatory standards for indoor pollutants--". I say thank God for that, especially when the so called "indoor pollutant" is an integral part of God's earth!

Sincerely,

Dr. Lyda W. Hersloff

Dr. Lyda W. Hersloff
Radioecologist

10854 Diane Drive
Golden, Colorado 80401.

received
7/18/80

TENNESSEE VALLEY AUTHORITY
NORRIS, TENNESSEE 37828

JUL 17 1980

Dr. William H. Ellett
Task Force Chairman
Office of Radiation Programs, ANR-460
U.S. Environmental Protection Agency
Washington, D.C. 20460

Dear Dr. Ellett:

We are pleased to provide the enclosed comments on the Work Plan of the Task Force established by the Radiation Policy Council to consider the issue of radon in inhabited structures as published in the June 27, 1980, Federal Register (45 FR 43508-43512). It is currently planned that TVA representatives will attend the regional public meeting scheduled for August 5, 1980, in Atlanta, Georgia, as also published in the June 27, 1980, Federal Register (45 FR 43512). TVA will not present oral statements at the meeting regarding the control of radon in inhabited structures.

TVA is interested in this issue because it concerns some of our program areas (i.e., energy conservation for housing). If we can offer any technical assistance to the Radiation Policy Council Task Force or in any way participate in consideration of this issue, please let us know. In any event, we desire to be kept informed of any future developments and results of the studies which the Task Force will undertake.

Sincerely,

for:
Mohamed T. El-Ashry, Ph.D.
Director of Environmental Quality

Enclosure

7/23/80

COMMENTS ON RADIATION POLICY COUNCIL TASK FORCE WORK PLAN REGARDING CONTROL OF RADON IN INHABITED STRUCTURES (45 FR 43508-43512)

1. The Task Force states that "the average level of radon in U.S. homes and the distribution of values about this average are very poorly known" (Page 43511, column 3, paragraph 3). This implies the existence of a meaningful average background level of radon. The usage of such terms as "anomalously high," "unusually high," and "high" in the Summary of Background Information section of the Work Plan regarding observed levels of radon, also implies that a discrete average level exists to make a comparison and subsequent determination. This implication may not be true. Background radiation from non-radon related sources varies significantly in the United States. It can be anticipated that the same will be true for radon; that is, further studies may show that designation of a national background value is not meaningful. Extreme caution should be used in designating or even suggesting the possibility of national standards or guides until more data are available regarding background distributions applicable to many specific geographical areas. Such data should be gathered for both conventional and energy-efficient homes. Further, setting permissible gross (i.e., including background) levels on radon and its progeny in specific geographical areas without full consideration of the impacts of setting a similar level to be applicable nationwide does not appear to be justified.

2. It is presumed that health effect estimates will be made by extrapolating available data on cancer incidence among miners. Cumulative doses and dose rates among members of the general public will be different from those doses and dose rates among miners and are received under different conditions. These differences should be explored by the Task Force in their deliberations on the identified options. This consideration is especially important because of the potential high costs which may be incurred by various groups and individuals to meet any radon standards or guides which may be adopted. We believe that the number of instances of financial hardship could be large.

3. <u>Page 43510, Alabama and Neighboring States TVA</u> - The 11 "homes" noted in column 2 for first floors were actually 5 residences and 6 commercial and/or educational structures. Also, the 73 and 36 percent values listed in the sixth and seventh columns, respectively, are for all (phosphate slag and control) basements. This fact is not obvious from the table.

4. <u>Page 43510, last two table columns</u> - To aid in the identification of significant radon and radon decay product levels, it is recommended that the Task Force's position paper include detailed information regarding the distribution and range of measured working levels (WL) rather than present percentage values above specific working levels, such as the percentages above 0.01 and 0.02 WL given in the table.

5. <u>Page 43511, column 2, third paragraph</u> - It is stated that the third part of the Task Force's position paper will discuss "a survey of current Federal Programs." The Task Force should also address programs being carried on or planned by non-Federal groups.

NCRP

National Council on Radiation Protection and Measurements

7910 WOODMONT AVENUE, SUITE 1016, WASHINGTON, D. C. 20014 AREA CODE (301) 657-2652

WARREN K. SINCLAIR, *President*
HYMER L. FRIEDELL, M.D., *Vice President*
W. ROGER NEY, *Executive Director*

July 17, 1980

William H. Ellett, Ph.D.
Office of Radiation Programs
ANR-460
U.S. Environmental Protection Agency
Washington, D.C. 20460

Dear Dr. Ellett;

This is in response to the request for comments that appeared in the Federal Register, Friday, June 27, 1980 on the subject of radon in inhabited structures.

The NCRP has undertaken a study of a closely related subject and, as a result of that study, the NCRP would like to offer the attached comments. It is unfortunate that, due to the time constraints placed upon the work of your task force, we are not able to offer a more refined and more complete set of comments but I believe that these comments may prove helpful in your work.

There is one very imp [illegible] pect of the whole problem of radon in inhabited structures that needs [illegible] reat deal of emphasis. The results of our studies emphasize the fact that great care must be exercised in determining radon concentrations in dwellings to avoid hasty and imprudent action on the basis of other than annual average Working Level determinations. It is essential that results be obtained on the basis of average annual levels. Your Federal Register notice implies that this will be the case.

If there are questions or if you need more information please contact us. Thank you for this opportunity to comment.

Sincerely yours,

James A. Spahn
Staff Assistant

enclosure

JAS/kak

received
7/18/80

NCRP Response to Federal Register of 6/27/80 Request for Public Comment on Radon in Inhabited Structures

1. Introduction

It is important to use the knowledge gained through the uranium mining experience to predict lung cancer risk which could arise through a particular environmental practice. Since radon daughters are ubiquitous and elevated exposures of individuals or relatively large groups are possible, it is desirable to also quantitate the risk. Elevated radon daughter exposures are now reported in association with a variety of ordinary circumstances as well as unusual or occupational settings. Some of these are: homes that are poorly ventilated (especially single family dwellings where living space is close to the soil); basements; crawl spaces with no concrete foundation; areas adjacent to or homes built upon uranium mill tailings; homes that are supplied with radon-rich water; and homes near phosphate-rich areas or near phosphate tailings piles, to name but a few. As more measurements of natural radioactivity are performed, it will be necessary to establish whether specific situations are tolerable with regard to lung cancer risk. The following model has been developed so that individual exposures may be assessed.

2. Predictive Model

Bronchogenic lung cancer induced by long exposure to elevated levels (a few hundred working level months or more) of radon daughters in underground mines is well established (Lundin _et al_., 1971; Snihs, 1973; Sevc _et al_., 1976; Kunz and Sevc, 1978; Axelson and Sundell, 1978; Archer _et al_., 1979; Kunz _et al_., 1979). Based upon the exposures described in the Federal Register notice, normal environmental exposures could be near 0.2 WLM per year resulting in lifetime exposure of 85 x 0.2 = 17 WLM. Snihs (1973) considers that the lowest underground exposure which resulted in an apparent increase in lung cancer deaths is about 15 WLM. Some argue that lung cancer mortality in miners at these low levels of exposure is not significantly different from expected (Stewart, 1979) and that a threshold for radon daughter-induced lung cancer exists. Archer _et al_. (1979) conclude from their analysis of 18 different mining populations in different countries that, if a threshold exists, it is below the range from 20 to 30 WLM. Thus, the possibility exists that environmental or slightly elevated radon daughter levels do not induce lung cancer. The data from the higher mine exposures might be used to estimate possible lung cancer rates at low radon daughter levels, but many times the temporal conditions for mining versus environmental exposure (duration and age at first exposure) make it difficult to relate the two directly.

In spite of the difficulties, this approach has been taken here and by others (Stranden, 1980; Cohen and Cohen, 1980). Spontaneous lung cancer mortality (nonsmoking related) offers some guidance since the model should not produce a lung cancer incidence that is greater than observed for ordinary background levels of radon daughters. The present model is relatively simple and yields results that are consistent with the underground mining experience. The model is based upon the information about lung cancer enumerated below which appears reasonably certain. The confounding effect of smoking is considered later.

A. The highest reported rate of appearance of lung cancer attributable to radon daughters appears to occur at low exposure rates (< 0.01 WL) and is 50 x 10^{-6} per year per WLM. At higher exposure rates (~ 1 WL) the incidence is less than one-half this. One average value of this risk coefficient (10 x 10^{-6} per year per WLM) was obtained by estimating lung cancers in a group of uranium miners without regard to exposure rate or age at start of exposure (Kunz et al., 1979). The average value of 10 x 10^{-6} per year per WLM is recommended at this time.

B. The rate of appearance of lung cancer after a single external radiation exposure seems reasonably uniform with time. Support for this comes from the Japanese A-bomb data (Beebe et al., 1978).

C. The appearance rate for a single exposure is highest when age at exposure is highest (Beebe et al., 1978). This is also seen in the Czechoslovakian mining data following exposure to radon daughters over an extended period (Sevc et al., 1976).

D. The incidence of lung cancer before the age of 40 is very low (Saccomano et al., 1974; Israel and Chachinian, 1976).

E. The median age associated with lung cancer appearance in miners is about 60 in nonsmokers and 50+ in smokers regardless of the age at first start of mining (Archer et al., 1979).

F. Radon daughter-induced lung cancer rarely, if ever, appears at less than 7 years after exposure (Archer et al., 1979).

G. The time for tumor growth from bizarre cells to frank appearance is about 5 years (Saccomano et al., 1974).

Raissland et al. (1976) originally proposed a model specifically for the appearance of leukemia in a population occupationally exposed to chronic external radiation. The annual appearance rate of tumors attributable to a single exposure was assumed constant and commenced after a constant latent interval. The model for lung cancer developed here is based on this idea, but differs in two ways: One, the incidence does not manifest itself until age 40 regardless of the age at exposure, and after age 40 a minimum single value for the latent interval of 5 years applies; two, the tumor rate is not uniform with time but is corrected from the time of exposure by an exponential factor with an effective half-life of 20 years. The annual appearance rates following a single exposure, first at age 20 and then at age 45, are shown schematically in Figure 1. The uncorrected rates are shown in Curves (a) and (b) and the corrected rates by Curves (c) and (d).

The exponential factor is justified by assuming that a repair or loss half-time exists for stem cells that are transformed by alpha radiation (Harley and Pasternack, 1980). By using this approach, and correcting the attributable risk for each year subsequent to exposure with a 20 year half-life, the calculated lifetime risks agree well with those observed in the uranium mining studies, including the fact that miners first exposed at age 40 have a higher lifetime lung cancer risk than those first exposed at age 20. The lifetime risk of lung cancer calculated here is also corrected by an appropriate life table value to account for the slight reduction in lung cancers due to death from other causes.

It is not strictly possible to check the performance of the model with natural background exposures to radon daughters. The model would project, however, that about 20 percent of the spontaneous (nonsmoking) lung cancer incidence could be attributed to natural radon daughter exposure.

3. Lifetime Lung Cancer Risks from Model Predictions

The basic data from the underground mining epidemiological studies cannot be applied directly to environmental situations. The common factor, however, should exist in the risk per rad for bronchial dose. The lifetime lung cancer attributable to an absorbed dose of 1 rad, using the conversion factor of 0.5 rad/WLM estimated for miners, as well as lifetime risk for chronic exposure to 1 rad per year, have been calculated. Table 1 shows the results of these calculations for exposures

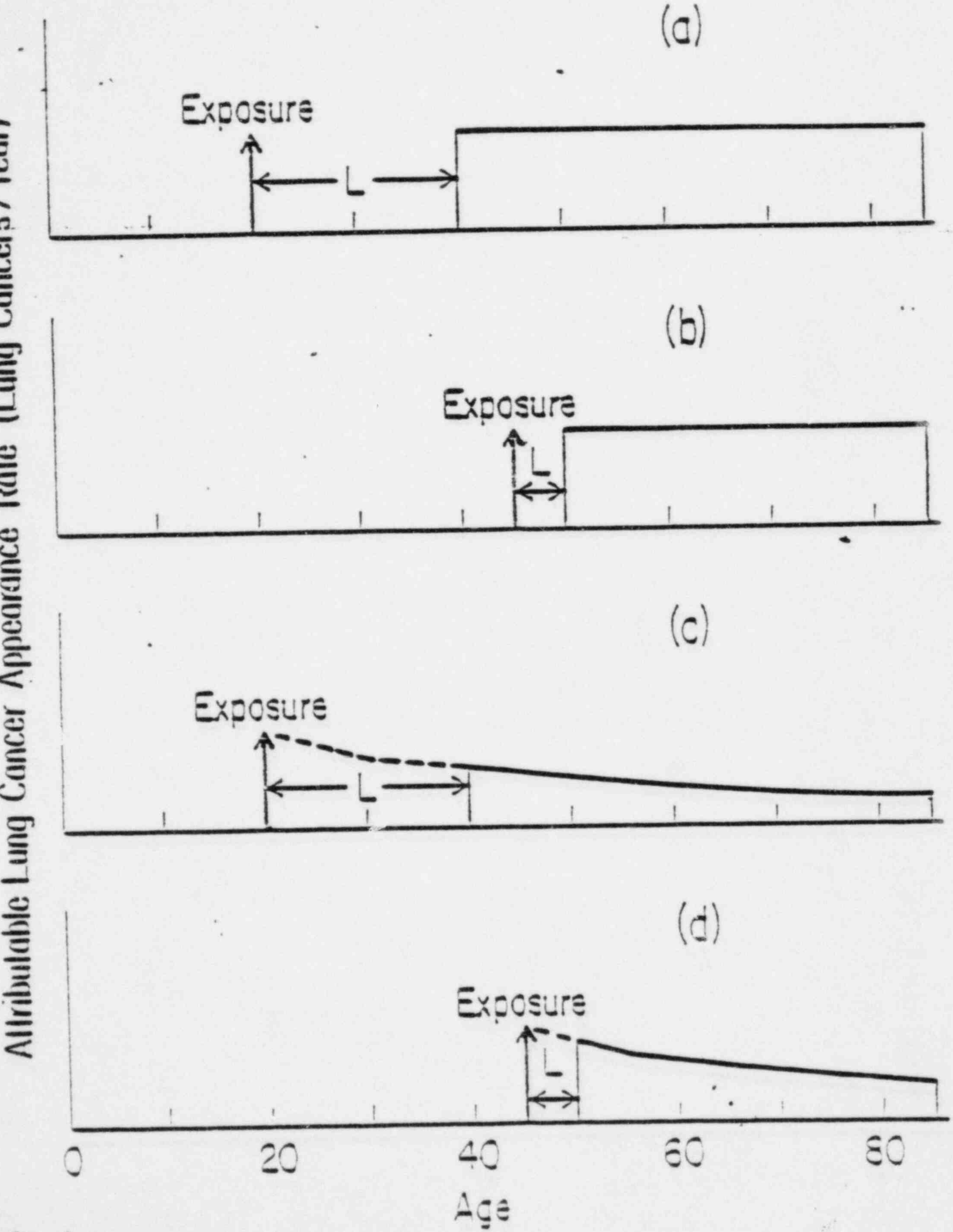(a)
Exposure
L
(b)
Exposure
L
(c)
Exposure
L
(d)
Exposure
L
Attributable Lung Cancer Appearance Rate (Lung Cancers / Year)
0
20
40
60
80
Age

Fig. 1

TABLE I LIFETIME LUNG CANCER RISK PER RAD PER YEAR FROM RADON DAUGHTER EXPOSURE. LIFETIME RISK AS A FUNCTION OF AGE AND DURATION OF EXPOSURE.

Exposure Duration	Lifetime Lung Cancer Risk								Lung Cancers in a Population of 10^5 Persons*
	Age at First Exposure								
	1	10	20	30	40	50	60	70.	
1 Year	9.2×10^{-5}	1.3×10^{-4}	1.8×10^{-4}	2.6×10^{-4}	3.0×10^{-4}	2.4×10^{-4}	1.8×10^{-4}	1.0×10^{-4}	19
5 Years	4.8×10^{-4}	7.2×10^{-4}	9.8×10^{-4}	1.4×10^{-3}	1.5×10^{-3}	1.2×10^{-3}	7.8×10^{-4}	4.0×10^{-4}	94
10 Years	1.1×10^{-3}	1.6×10^{-3}	2.2×10^{-3}	3.0×10^{-3}	2.8×10^{-3}	2.0×10^{-3}	1.3×10^{-3}	5.4×10^{-4}	150
10 Years	4.8×10^{-3}	6.8×10^{-3}	7.8×10^{-3}	7.8×10^{-3}	6.0×10^{-3}	3.6×10^{-3}	1.8×10^{-3}	5.4×10^{-4}	540
Life	1.3×10^{-2}	1.3×10^{-2}	1.1×10^{-2}	1.1×10^{-2}	6.4×10^{-3}	3.8×10^{-3}	1.8×10^{-3}	5.4×10^{-4}	800

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*For a population with age characteristics equal to that in the whole United States in 1975.

beginning at ages 1, 10, 20, 30, 40, 50, 60, and 70 years for durations of 1, 5, 10, 30, and total to age 85 years. Since the ages within an exposed group vary, it is also of interest to know the lifetime risk for a population with age characteristics like those of the United States. This is shown in the last column of Table 1 using the 1975 age distribution for the U.S. (WHO, 1978).

Bronchial dose has only recently been estimated in environmental exposures. Therefore, two other lifetime risk tables are derived from Table 1 that relate to the measured environmental quantities, WLM and radon concentration in pCi ^{222}Rn/m^3.

The average environmental dose conversion factors for the adult male, female, ten-year old child, and infant are 0.71, 0.64, 1.2, and 0.64 rad/WLM respectively. The differences reflect primarily reduced breathing rates under normal environmental conditions, different lung morphometry, and the increased percentage of unattached RaA in ordinary atmospheres. Thus, an environmental exposure is expected to be somewhat more productive of tumors than an occupational exposure where the factor is 0.5 rad/WLM. The system can be simplified considerably if we accept the environmental dose conversion factor of 0.7 rad/WLM. The lifetime risk estimated for women or that which includes the effect of the higher dose conversion factor in childhood is within 10 percent of that adopting the factor for adult males at all ages. The lifetime risks per environmental WLM per year are shown in Table 2 for the conditions given with Table 1.

For the case of exposure measured as radon concentration and time, the average annual bronchial dose to adult males from the daughters associated with 1 pCi ^{222}Rn/m^3 can be calculated as follows:

$$\text{Dose}\left(\frac{\text{rad}}{\text{year}} \text{ per } \frac{\text{pCi } ^{222}\text{Rn}}{\text{m}^3}\right) = 0.0003\left(\frac{\text{hours per day active}}{24}\right) + 0.0002\left(\frac{\text{hours per day resting}}{24}\right)$$

Assuming 16 hours per day are active and 8 hours per day are spent resting,

$$\text{Dose} = 0.00027 \frac{\text{rad}}{\text{year}} \text{ per } \frac{\text{pCi } ^{222}\text{Rn}}{\text{m}^3}$$

ABLE 2 LIFETIME LUNG CANCER RISK UNDER ENVIRONMENTAL CONDITIONS PER WLM PER YEAR[†]. LIFETIME RISK AS A FUNCTION OF AGE AND DURATION OF EXPOSURE

	Lifetime Lung Cancer Risk								Lung Cancers in a Population
xposure	Age at First Exposure								
uration	1	10	20	30	40	50	60	70	of 10^5 Persons[*]
1 Year	6.4×10^{-5}	9.1×10^{-5}	1.3×10^{-4}	1.8×10^{-4}	2.1×10^{-4}	1.7×10^{-4}	1.3×10^{-4}	7.0×10^{-5}	13
5 Years	3.4×10^{-4}	5.0×10^{-4}	$6,9 \times 10^{-4}$	9.8×10^{-4}	1.0×10^{-3}	8.4×10^{-4}	5.5×10^{-4}	2.8×10^{-4}	66
0 Years	7.7×10^{-4}	1.1×10^{-3}	1.5×10^{-3}	2.1×10^{-3}	2.0×10^{-3}	1.4×10^{-3}	9.1×10^{-4}	3.8×10^{-4}	130
0 Years	3.4×10^{-3}	4.8×10^{-3}	5.5×10^{-3}	5.5×10^{-3}	4.2×10^{-3}	2.5×10^{-3}	1.3×10^{-3}	3.8×10^{-4}	380
ife	9.1×10^{-3}	9.1×10^{-3}	7.7×10^{-3}	7.7×10^{-3}	4.5×10^{-3}	2.7×10^{-3}	1.3×10^{-3}	3.8×10^{-4}	560

For Radon daughters measured under environmental rather than underground mining conditions.

For a population with age characteristics equal to that in the whole United States in 1975.

As with the WLM calculations, the values for women or including the effect of the different dose conversion factor for infants and children are within 10 percent of the value calculated by using the factor for adult males. Table 3 shows the lifetime risks for annual exposures to 1 pCi $^{222}Rn/m^3$ for the conditions given with Table 1.

4. Guidelines for Population Size for Exposure in Special Situations

The reciprocals of the lifetime risks in Tables 2 and 3 are estimates of the size of the population which can be exposed to either 1 WLM or 1 pCi $^{222}Rn/m^3$ per year for the various environmental exposure intervals to produce one calculated lung cancer fatality. These population size estimates are shown in Table 4.

For a specific exposure, the population size is calculated from the lifetime risks tabulated using

$$\text{Population Size} = \frac{1}{(LR)_D(E)}$$

where

$(LR)_D$ = Lifetime risk for the appropriate exposure duration, D, under consideration. Lifetime risk is obtained from Tables 2 and 3 and depends upon exposure unit chosen (WLM per year or $\frac{pCi\ ^{222}Rn}{m^3}$).

E = Exposure from a given environmental practice. Either WLM per year or pCi $^{222}Rn/m^3$, whichever is available.

The conservative maximum population size calculated here should allow only a small risk of including the one lung cancer.

Tables 1 to 3 have been developed without regard to differences between smokers and nonsmokers. Axelson and Sundell (1968) report that, for a small number of lung cancer cases developing in zinc-lead miners in Sweden, the lifetime risk for nonsmokers actually appears to be higher than for smokers. The average time of appearance of the tumors in smokers, however, is about 9 years earlier than in nonsmokers. This possible protective effect of smoking is now supported by dogs exposed to radon daughters with and without cigarette smoke. Axelson and Sundell (1968) tentatively ascribed this to the protective effect of a thickened mucus barrier in the airways, but suggested that, once initiated, the promotional effect of

TABLE 1 LIFETIME LUNG CANCER RISK UNDER ENVIRONMENTAL CONDITIONS[†] PER pCi $^{222}Rn/m^3$. LIFETIME RISK AS A FUNCTION OF AGE AND DURATION OF EXPOSURE.

Exposure	Lifetime Lung Cancer Risk								Lung Cancers in
	Age at First Exposure								a Population
Duration	1	10	20	30	40	50	60	70	of 10^5 Persons*
1 Year	2.5×10^{-8}	3.6×10^{-8}	5.0×10^{-8}	7.1×10^{-8}	8.3×10^{-8}	6.7×10^{-8}	4.8×10^{-8}	2.7×10^{-8}	0.0051
5 Years	1.3×10^{-7}	1.9×10^{-7}	2.7×10^{-7}	3.8×10^{-7}	4.0×10^{-7}	3.1×10^{-7}	2.1×10^{-7}	1.1×10^{-7}	0.026
10 Years	2.9×10^{-7}	4.2×10^{-7}	5.8×10^{-7}	8.1×10^{-7}	7.5×10^{-7}	5.6×10^{-7}	3.6×10^{-7}	1.5×10^{-7}	0.051
30 Years	1.3×10^{-6}	1.8×10^{-6}	2.1×10^{-6}	2.1×10^{-6}	1.6×10^{-6}	1.0×10^{-6}	4.8×10^{-7}	1.5×10^{-7}	0.14
Life	3.6×10^{-6}	3.5×10^{-6}	3.0×10^{-6}	2.5×10^{-6}	1.7×10^{-6}	1.0×10^{-6}	4.8×10^{-7}	1.5×10^{-7}	0.21

[†] Radon to radon daughter ratio Rn/RaA/RaB/RaC equal to 1/0.9/0.7/0.7 unattached $\frac{RaA}{Rn}$ equal to 0.07.

[*] For a population with age characteristics equal to that in the whole United States in 1975.

TABLE 4 MAXIMUM NUMBER OF PERSONS EXPOSED TO RADON DAUGHTERS UNDER ENVIRONMENTAL CONDITIONS THAT WILL PRODUCE NO ATTRIBUTABLE LUNG CANCER. POPULATION AGE COMPOSITION SHOULD HAVE CHARACTERISTICS OF TOTAL U.S. POPULATION 1975

Exposure Duration	Maximum Population Size (Persons) for Exposure to 1 WLM/Year and Indicated Duration	Maximum Population Size (Persons) for Exposure to 1 pCi $^{222}Rn/m^3$ and Indicated Duration†
1 Year	7.7×10^3	2.0×10^7
5 Years	1.5×10^3	3.8×10^6
10 Years	7.7×10^2	2.0×10^6
30 Years	2.6×10^2	7.1×10^5
Life	1.8×10^2	4.8×10^5

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†Radon to radon daughter ratio Rn/RaA/RaB/RaC equal to 1/0.9/0.7/0.7 and unattached $\frac{RaA}{Rn}$ equal to 0.07.

tobacco smoke causes tumors to appear faster. Archer et al. (1979) indicate that this effect may also be evident in the U.S. data, but at present the results are not clearcut. The model could be adapted on this basis to allow for a longer tumor growth time for nonsmokers than 5 years and a slightly lower risk coefficient than 10×10^{-6} per year per WLM for smokers, but not enough data are available to model with any certainty. Until more data become available, the predictive model applied here should provide a conservative estimate applicable to smokers and nonsmokers.

5. Summary

The model developed here is intended to utilize the lung cancer experience obtained in epidemiological studies of underground miners at high levels of radon daughter exposure to extrapolate to environmental levels. It is not known if this approach is valid, but it does allow an upper limit estimate of lung cancer production. The criterion for the model is that it should fit the existing underground mining lung cancer data well. A model that expresses lung cancer risk uniformly with time after exposure (with the restriction that tumors do not occur either before a 5-year latent interval or age 40) and corrected from year of exposure by an exponential factor which accounts for cellular repair and an appropriate life table value to account for competing risks of death, satisfies this criterion. Lifetime lung cancer risks per rad, per WLM/year, and per pCi ^{222}Rn/m^3 are then readily tabulated for different exposure intervals and are given in Tables 1, 2, and 3. The maximum population size that should be exposed to a particular radon daughter level resulting from a specific practice while allowing only a small risk of producing a lung cancer is shown in Table 4.

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COLORADO DEPARTMENT OF HEALTH

Richard D. Lamm
Governor

Frank A. Traylor, M.D.
Executive Director

July 21, 1980

William H. Ellett, Ph.D.
Task Force Chairman
Office of Radiation Programs
ANR-460
U.S. Environmental Protection Agency
Washington, D.C. 20460

Dear Dr. Ellett:

I am writing to you in reference to the Federal Register notice Friday, June 27, 1980, regarding the Radiation Policy Council Task Force which you chair.

My comment to you regarding the topic that you are to address is that the impact of radon in drinking water on concentrations within structures should be included in your efforts if you have not already done so.

Best personal regards.

Sincerely,

Albert J. Hazle, Director
Radiation and Hazardous
Wastes Control Division

AJH:bjw

cc: Hall Bohlinger, Louisiana

Received 7/30/[illegible]

4210 EAST 11TH AVENUE DENVER, COLORADO 80220 PHONE (303) 320-8333

ENERGY
CONSERVATION & CONTROL
SYSTEMS, INC.

William S. Geiger
Joyce P. Geiger

July 21, 1980

William H. Ellett, PhD.
Task Force Chairman
Office of Radiation Programs, ANR-460
U. S. Environmental Protection Agency
Washington, D. C. 20460

Dear Sir:

I support the Radiation Policy Council decision to prepare a position paper on radon control. This information is urgently needed because of the inconsistent federal actions and public misconceptions involving radon and low level radiation exposures.

The actions undertaken to reduce radon exposures from uranium mill tailings and the EPA recommendations to the Governor of Florida are not only very expensive, but also have added to the media and public misunderstanding of the effects of low level radiation and the significance of the "action levels". On the other hand, the Federal Weatherization Program - Environmental Assessment acknowledged potential adverse effects from increased radon and other pollutants, but they were not quantified and were ignored in the conclusion and recommendations even though the potential risks from radon exposure, based on the EPA model, appear to be much greater for these conservation programs than the cases requiring corrective actions! The proposed position paper should help alleviate such inconsistent approaches by various agencies in the government.

The use of the "Working Level" unit as a primary exposure guideline should be discontinued. It could continue to be used as a derived control level, for example as an alternate to "Maximum Permissible Concentration" values for each isotope for radon and its daughters in air. The consistent use of radiation exposure units (Rem) would help alleviate public and media misconceptions and provide for improved perspective by permitting direct comparisons with other exposures including such items as the controversy over venting of krypton gases from the Three Mile Island Plant.

More specific comments on the Federal Register are as follows:

<u>Technical Problems</u>

The notice discusses technical problems including existing instrumentation, average levels, the distribution of values,

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and the fact that radon levels in a home "vary considerably depending on a host of factors". The existing data have not addressed these other variables except in very general terms. For example, the Federal Register of June 24, 1976 used "high ventilation area", and this notice uses "energy efficient houses" and "doors and windows closed". Additional sampling of this nature would be of little or no value even with "perfect instrumentation" because of the increases being incurred by the current energy conservation weatherization measures. The existing "average values" and data on the effects of ventilation rates is adequate to determine the average exposure and potential risk from radon exposures for a range of scenarios.

Research should concentrate on controlled experiments rather than massive sampling of homes. In this way, the effects of the significant parameters including source terms and ventilation rates can be quantified and measurement techniques standardized. Data such as the following would provide valuable information for evaluating alternative methods of controlling radon exponsures:

Dose Models

- radon and progeny by isotope
- dust particle size
- free ion fraction
- working level conversions
- adult parameters
- child parameters

Risk Assessment

- dose vs. risk model
- comparisons and perspective
  - historical cencer incidence and variations
    - smoking
  - historical household risks
    - falls
    - fire and explosion
    - drowning
    - electrical
    - location (transportation requirements)
    - floods, tornados, lightning, etc.
    - poisons
    - space heating
    - crime and violence

Source Terms

- soil radon emissions rates
  - soil type/area
  - radium concentration
  - external gamma radiation correlations

- Material radon emission rates
  - Structural materials
    - phosphate slag aggregates
    - fly ash
    - gypsum board
      - phosphate by-product
  - Decorative
    - tiles
    - rock, brick, etc. (fireplace)

Social-political Problems

The Federal actions in Grand Junction and the recommendations to the State of Florida have only added to the confusion and misunderstandings of the public and have provided material for sensationalism by the media. Editorials and comments in the Florida newspapers questioned the difference in action levels from the Surgeon General's recommendations and ask for a determination of the "safe level". The EPA public meeting in Bartow, Florida was a dissappointment. Members of the public, whose homes were involved in the surveys, stood in line to get "the number" for their home and compare it with their neighbors' and the proposed EPA action levels while wating for an EPA official from Washington to arrive to make a presentation. After approximately two hours, it was announced that the official would not be able to make the presentation at the meeting. Then, several technical presentations were made that dealt with radiation and the home surveys. However, most of the public and media had left the meeting, having given up on the official's attendance. The "technical presentations" for the few remaining people appeared to only add to the already existing confusion.

The establishment of mandatory action levels based on workding levels, fails to recognize that the risk estimates are based on the "linear hypothesis" and that no "threshold effect" has been found for low level radiation exposures. Furthermore, considering the host of factors affecting the "working level" or risk in any home, the current practice of just measuring the working level is totally inadequate, unenforceable and could contribute to the victimization of home owners.

The expenditure of vast sums of federal money, or private money if mandated by regulation, to reduce the measured working level to comply with an arbritary limit for the purpose of reducing the cancer risk is incongruous with the facts that about 25% of the population will get cancer and that such efforts would have insignificant reductions in this rate. There is much greater potential benefit for mankind by spending the money on cancer research.

Since the "life style" of the occupants of a house has such a great effect on the WL, practices of withholding mortgages, as mentioned in the notice, based on WL measurements alone, should be stopped. Separate measurement of source terms, ventilation rates, etc. would provide more useful information and a better comparison of buildings.

Recommendations

Federal actions concerning indoor radon exposure should be of an advisory nature without mandatory action levels. Guidance should be developed on the relation of the source terms, ventilation, and other parameters on the radon and progeny concentrations or WL. Dose and risk models and risks assessments of other household hazards should be presented for comparison and to support any recommended levels or guidelines.

In this manner, alternatives for obtaining acceptable risks can be evaluated in a logical manner and decisions concerning additional conservation measures or corrective actions can be made on a rational basis.

Respectfully submitted,

William S. Geiger jg

William S. Geiger

WSG:jg

Copies to:
Governgor Robert Graham, Tallahassee, Fl.
Congressman Andy Ireland, Lakeland, Fl.

U.S. Radiation Policy Council
OSTP/Executive Office of the President
Washington, D.C. 20500

Statement of: Anthony V. Nero, Jr., San Francisco, July 31, 1980

mailing address:
Ventilation and Indoor Air Quality Program
Building 90, Room 3058
Lawrence Berkeley Laboratory
Berkeley, CA 94720

The Radiation Policy Council has an important and difficult charge in its responsibility to help the United States rationalize its handling of radiation exposure questions. Existing or potential radiation exposures arise in a variety of contexts. It is important that the regulatory structure be designed to handle this variety of situations in a consistent manner, that corresponding administrative responsibilities be given to the appropriate authorities, and that the underlying program of research to elucidate actual or potential effects of radiation be effectively coordinated. In addition, the Radiation Policy Council should consider carefully the role it might play in education of the public on the nature and extent of radiation-related risks. This will certainly be difficult, since for essentially no risk can it be said that public information is adequate, so that it has been exceptionally difficult to establish a context for public consideration of radiation-related risks.

These remarks apply for the most part to the full scope of the Radiation Policy Council. They apply in particular to the area being considered by the task force on indoor radon, to which I will devote the rest of my comments. The work of this task force is extremely important since it now appears that the most significant portion of natural radiation exposures may occur from this one source, i.e., from exposures of the general public to radon daughters in their own homes. However, effective control of these exposures is made difficult by the lack of a regulatory philosophy for indoor air quality and by limited information both on the radon levels that now exist and on the methods that could control these levels. Furthermore, the limited data available on the effects of rather large integrated exposures to radon daughters on miners, i.e., some associated risk of lung cancer, does not lend itself very directly to estimation of the effects of long-term exposures of the general population to typical indoor levels. However, it is important to note that there is mounting evidence to suggest that a significant portion of the population receives lifetime doses that are more typically associated with uranium miners than with background exposures of the general public. Whatever percentage of the population receives doses in the occupational range, whether 1% or 5%, these people deserve special attention. Further, it appears that the bulk of the population exposure to radon, including that at high levels, occurs in ordinary houses, not ones associated with special industrial activities, not houses that have exceptionally low air exchange rates.

That the bulk of the exposure should occur in ordinary situations poses a regulatory problem of a different kind than has been dealt with before, either for radioactivity or for other contaminants. The fact that we are sepaking of the interior of private dwellings, rather than of air basins, poses a different kind of question than has been faced in the formulation of outdoor, so-called ambient, air quality standards. Generally speaking, the latter standards are designed to set limits on population exposures, i.e., those in an air basin, but - except for limitation of occupational exposures at relatively high levels - standards have not been designed to limit the risk of each individual. A fundamental difficulty with limiting individual risks per se, is that they will depend on the habits of the individual.

Furthermore, standards pertaining to radiation in particular have generally evolved in a rather different context than that to be considered for indoor radon. Much of the structure for developing and implementing standards has been designed for the case where radionuclides are made by humans or are encountered in occupational contexts, where the exposure arises from some industrial acitvity, and - usually - where the risks and corresponding control costs are relatively small compared with the value of the activity. Because of the comparatively small risks, it is often possible to adopt a relatively conservative attitude about the level of acceptable risk or, to put it in another way, about the costs that ought to be incurred to avert the presumed risk.

Most of these favorable circumstances are absent in the case at hand. The radiation of concern is not only natural, it occurs in every home. For most cases, the source is not an unusual industrial activity, but the soil under the house or the materials of which it is constructed. And, for the higher levels encountered, the apparent risk is substantial, so that control measures might be considered even at great cost. But even for the typical case, the risk may be high enough that a "conservative" regulatory approach is probably not appropriate. Rather, realistic appraisals must be made of the radon risk and of other costs and benefits, some of which will inevitably not be quantifiable.

Having alluded to "typical" and "higher" concentrations, it is unfortunately difficult to be much more specific about the levels to which the U.S. public is exposed, or in fact about the corresponding health effects. It can be said that typical houses have daughter concentrations of 0.001 to 0.02 WL. However, many appear to have concentrations considerably above this range, perhaps even in the vicinity of 0.1 WL or greater, pressing the occupational dose limit. It can be said that long-term exposures at the occupational dose limit yield increased rates of lung cancer. Whether the same is true at more typical levels is highly uncertain, although a linear response to low levels is typically presumed for regulatory applications where a conservative stance is appropriate. But too little is known to make firmer statements.

For this reason, a vigorous research program is required to more fully characterize existing concentrations, including their range and distribution, to better understand the dependence of health effects on both levels and the exposed population, and to determine the effect of possible control measures. A number of efforts have been addressing apsects of these questions, in some cases for many years. However, although many efforts are proceeding at universities, EPA laboratories, and DOE laboratories, this diverse effort requires good communication, willing cooperation, and careful coordination. I am heartened at the communication and cooperation among the researchers on indoor radon. But, the Radiation Policy Council should examine carefully how effective coordination of existing efforts can be ensured and how work on key areas not adequately covered can begin, presumably building on existing capabilities. The resources for performing the important work on this question are rare, in terms of both people and laboratories. Duplication should be avoided and, I should add, a proper balance maintained between large field survey work, small field tests, instrumentation development, and - at the base - laboratory research to understand what is being measured and how control techniques work.

Effective design and implementation of the necessary research program, with both short-term and long-term objectives, requires at a minimum a technical advisory group, as has been suggested, I believe in the task group on radon. Consistent diligence will be required for any coordination mechanism to meet immediate, and seemingly urgent, needs while maintaining adequate emphasis on investigation of basic questions that require, not only effort, but time. It may be appropriate to consider an indoor radon institute that would carry out part of the needed work, but would have an added responsibility for integration and coordination. This would help to keep the long-term goals in view, while minimizing duplication and time. As for the seemingly urgent goals, I am confident that - with the pressures under which the federal agencies work - sufficient emphasis will be placed on "immediate" needs.

One of the apparent immediate needs is to identify that portion of the population living in the higher livels, i.e., those getting the "occupational" doses to which I referred. Improving their situation will require a standard that limits the exposures of individuals. On the other hand, the population as a whole requires some level of protection, so that the average risk ought to be controlled, possibly to an order to magnitude lower level than the individual risk limit. I am, frankly, very uncomfortable, for conceptual and practical reasons, with the tendency to set limits in the vicinity of 0.01 - 0.02 WL that are supposed to apply to every individual. On the other hand, designing programs that assure that average exposures are at this level or lower appear practical. In particular, they would not depend on minor variations in construction practice and on lifestyle of the occupant, and they could rationally be area dependent, whereas a standard to control individual exposures cannot.

In looking at the proposed work of the indoor radon task force, I was disappointed to find that the fundamental question of regulatory approach, i.e., developing a conceptual or philosophic basis for indoor air quality standards, was nowhere mentioned. In particular, the question of individual versus population-average limits has to be examined. This notion is familiar in radiation protection, but not in the sense meant here, where it is difficult to set a low-level standard that pertains to every individual simply because 50 million environments are involved and because a standard that is met with one occupant of a structure may not be met when a different occupant moves in.

A specific possibility that needs to be considered is that mentioned above, i.e., adoption of a high-level individual limit, lower than the occupational dose limit, coupled with a program to control population exposures to an even lower level on an average basis. An operational trigger level for remedial action would be chosen to be some fraction of the individual limit considering variability from house to house, measurement uncertainties, and so on. I suggest this approach be considered by the task force in its position paper, by the Radiation Policy Council, and ultimately by those who recommend indoor air quality standards.

The question arises who should actually be charged with the responsibility for formulating any standard on indoor radon. It is clear that the Na-National Council on Radiation Protection and Measurements, with its long history of such work, should be a key participant in the process. However, if the NCRP is given the main responsibility for recommending a standard for adoption, it should be reminded of the differences between the case of indoor radon and the cases where industrial operations expose the public to man-made radionuclides at levels that are relatively easily controlled. Moreover, the structure of any standard should be consistent with the developing approach to indoor air quality standards in general.

I am afraid that I have suggested a difficult requirement for the task force on radon and, in turn, for the full Council, i.e., before we go about setting standards, we decide what they are supposed to do.

OCT 6 1980

Honorable Max Baucus
United States Senate
Washington, D.C. 20510

Dear Senator Baucus:

One of your staff investigators, Mr. Marc Smolonsky, has raised a number of questions regarding the significance of radon exposures of the U.S. population in a recent unsigned memorandum directed to the "Office of Radiation Programs Staff."

As Chief of the Branch responsible, among other charges, for the planning and coordination of ORP activities for evaluating and controlling indoor exposures of the U.S. population to radon, I offer the following in response to his questions:

1. What is the risk to the U.S. population from indoor radon?

Dr. Ellett, who is our principal authority on radiation bioeffects, has responded to you separately on this matter. These risk estimates are not new; they have been used in our regulatory program for several years and have been subjected to careful review by the Agency's Carcinogen Assessment Group. Specifically, the EPA Administrator's guidance to the Governor of Florida for protection of inhabitants of houses on reclaimed phosphate land (44 F.R. 38664, July 2, 1979) and the Agency's interim final standards for cleanup of uranium mill tailings under the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA) (45 F.R. 27366, April 22, 1980) were each based on the same risk coefficients for radon that were used to generate our estimate for the U.S. population due to indoor radon. The latter estimate has provided the basis for our concern and ongoing discussion with the Department of Energy on the Residential Conservation Program (RCS) (see the enclosed letter from David Hawkins to Maxine Savitz, December 19, 1979). DOE concurs with this concern and we are making good progress in jointly developing appropriate safeguards in the RCS program to avoid exacerbating indoor radon exposure.

2. Is radon exposure a national emergency?

3. Is ORP saving lives by rapidly initiating a program on radon exposure & controls?

These are matters of definition and judgment. The estimated size of the current and potential future annual impact of indoor radon exposure has been addressed by Dr. Ellett's letter and I concur with those estimates. Congress expressed its concern for one source of radon exposure (uranium mill tailings) by passing UMTRCA in 1978. In addition, DOE regulations to implement the RCS program were close to final promulgation when the ORP program effort was launched, and thus required a rapid response from us in order to be influenced in a timely way. I have supported the decision to rapidly initiate a comprehensive program on radon because I believe exposure to radon is a radiation protection problem of major and national significance, and that both the ongoing and potential future annual impact of radon on the U.S. population would be reduced by timely action on our part.

4. Is ORP using the best possible contractors to study radon?

ORP has, to the best of my knowledge, consistently sought and used the best qualified investigators and institutions known to us for each of the various subject areas in which we have sponsored work on radon. That is not to say that other qualified investigators and institutions do not exist. "Best possible" is an elusive concept and it is always possible to second-guess such judgments.

5. How does radon get into the environment?

Radon is a radioactive gas produced by the decay of radium, an element that is present in small quantities in most soils and geological formations. It is also found in significantly elevated concentrations in some ores, such as uranium, thorium, and phosphate ores. Radon gas migrates from underlying soil (and from some building materials) into houses, where it builds up to significant levels. In a few sections of the country radon in tap water (principally from deep wells in granitic formations) can be an additional source of indoor radon. Levels of radon in almost all indoor environments can be expected to be higher than normal outdoor levels. Our knowledge base for indoor levels is summarized in the recent Task Force report to the Radiation Policy Council enclosed in Dr. Ellett's letter to you. The buildup of indoor radon is mitigated by normal leakage of outside air into houses; hence our concern for not sealing up houses to an extreme degree for energy conservation purposes. In the out-of-doors, radon levels are generally low because of mixing into the large volume of air in the atmosphere and the prevailing movement of air masses across the continent and out to sea, where radon decays harmlessly.

In summary, I believe that it is reasonable to assume that the current impact of indoor radon exposure on the U.S. population is significant, that it could become considerably worsened by inappropriate energy conservation measures, and that protection of the public health from this hazard merits our urgent attention.

I hope the above comments and enclosures are helpful. If you or your staff have further questions, I can be reached by phone at (703) 557-8927.

Sincerely yours,

Allan C.B. Richardson, Chief
General Radiation Standards Branch
Criteria & Standards Division (ANR-460)
Office of Radiation Programs

3 Enclosures

cc: Mr. Stevens, Office of Legislative Affairs, EPA
Mr. Smolonsky
Dr. Rosenbaum (ANR-458)

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