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AN EXPERIMENTAL STUDY OF RADIATION DOSAGE FROM BREATHING RADON AND ITS DAUGHTER PRODUCTS*

by

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Now with General Dynamics Corporation, Electric Boat Division, Groton, Connecticut.

Perhaps it might be more cautious to say "A type of radiation exposure widely encountered etc
the numbers exposed to uranium and its fission products may not justify the term "main" here -

One of the main types of radiation exposure in the nuclear energy program at the present time is exposure to radon and airborne radon degradation products during uranium mining and early refining operations. Various estimates have been made of maximum permissible air concentrations based upon different hypotheses as to how these radioactive materials are handled in the body (1, 2, 3). The factual information upon which these calculations were based was small. The following experimental study was aimed at increasing the information as to the actual radiation dosage to different parts of the human respiratory system from exposure to radon and its radioactive degradation products.

Exposure Chamber and Sampling Procedures

All the human and animal exposures were performed using a chamber 3.9 feet by 2.9 feet by 6.4 feet of approximately 1800 liters capacity. The radon for the chamber was obtained from a 50 microcurie radium chloride source and displaced from the collecting flask into the exposure chamber by water displacement. The radon concentration in the chamber was originally measured by introducing samples into an ionization chamber attached to a vibrating reed electrometer. In later experiments, the radon was collected

quantitatively on charcoal and counted in a scintillation counter. The filterable radioactivity in the air, i.e., the radon daughter products, RaA Sp RA through RaC', was sampled by pulling chamber air through a millipore filter. Alpha activity on the filter paper was measured with a scintillation counter. The radon concentration used in most experiments was around 2.5×10^{-8} curies per liter.

Dependence of radon daughter product level upon dust load and air circulation in chamber.

why not use same designation as above i.e. $2.5 \times 10^{-}$

When the chamber was charged with radon at a level of 25×10^{-9} curies per liter shortly after the chamber air had been in free exchange with air from the out-of-doors with its normal dust load, measurements showed the radioactive degradation products in the air, through radium C', reached substantially radioactive equilibrium with the radon present. This level of equilibrium, ranging usually between 70 and 90 percent, depended very little, even in this small chamber, on whether the air was stirred with a fan or allowed to remain quiet.

On the other hand, when the dust load was reduced to very low levels by careful filtration of the air introduced into the chamber, the level of

the airborne degradation daughters fell to low levels compared to the equilibrium value. Values in quiet air were often less than 20% of the equilibrium value, and for agitated air, 2% of the equilibrium value.

The explanation for these lower values of radon degradation products in dust-free air, confirmed by other experiments, is that daughter products which are not trapped on dust particles have a much greater mobility and are more rapidly deposited on the chamber walls.

<u>Determination of biological half-life of radon daughters in the lungs of the rat.</u>

Previous calculations (4) and experiments (5, 6, 7) have indicated that for a human exposed to radon plus radon degradation products the principal radiation would be from radon degradation products deposited in the respiratory system. These calculations assume retention of radon degradation products in the lungs during complete radioactive decay. There are no published figures of actual measurements. Such measurements were therefore made with rats. Groups of four animals were exposed in the chamber to radon and radon degradation products in air with a normal

TABLE I. DATA FOR CALCULATION OF BIOLOGICAL HALF-LIFE

Rat	Weight	Time animal sacrificed after end of exposure min.	Cpm at equivalent decay time
		(1. Uncleaned air)	
26	167	5	384
27	181	5	381
28	178	140	241
29	175	140	215
		(2. Cleaned Air)	
31	192	8	740
32	183	8	640
33	200	81	500
34	190	81	450

Avg. of rats 26 and 27 = 383

Avg. of rats 28 and 29 = 228

Biological half-life = 180 m ok, checks 79%

Avg. of rats 31 and 32 = 690

Avg. of rats 33 and 34 = 475

Biological half-life = 135 m ok, checks 71%

$.595 = \frac{228}{383} = e^{-\frac{.693 \times 135}{T_{1/2}}} = e^{-.520}$

$.689 = \frac{475}{690} = e^{-\frac{.693 \times 73}{T_{1/2}}} = e^{-.37}$

dust load, and to carefully cleaned air. The results, shown in Table I, indicate that in each instance the biological half-life was 2 hours or greater, which is long compared with the effective radioactive half-life of about 35 minutes. Therefore, from a health physics viewpoint, the dosage correction that should be made to allow for removal of radioactive material from the lungs is small for rats, and presumably so for other experimental mammals and man.

This presumption may be challenged. The rat, is normally the inhabitant of a more dusty environment (close to the ground etc) than man hence may be presumed to have more rapid clearance mechanism for respiratory tract as an adaptation to its environment. Shows clear for man would and reduce the correction

Measurements of lung and trachael dosage in rats.

Measurements have been reported by other investigators in which relative radioactivity in the lungs of rats was measured following exposure to air containing radon degradation products somewhere near equilibrium with radon, and to air containing radon virtually free of degradation products (6). These results have been interpreted as showing that relatively the radiation dosage was due almost entirely to the radon degradation products present as particulates in the air, rather than to radon itself. However, no actual dosage measurements in terms of rad or rem units were made.

To provide data on this subject the following experiments were carried out. Rats were placed in the exposure chamber for at least 2 1/2 hours, removed, immediately sacrificed, and the radioactivity of lungs determined by gamma measurements with a well-type scintillation counter. The exposure period was long enough, some four times the effective half-life of the radon daughters, that an equilibrium amount of these materials in the lungs can be assumed. Average weight of the rat's lungs during life was assumed on the basis of our experimental measurements and Stokinger's values (8) as 0.43 percent of the total live weight. With suitable radioactive decay corrections and calibration factors, these data on retained radioactivity permitted calculation of the alpha radiation dose per gram per hour to the lungs of the experimental animals. Probably subject to correction depending on how close this mass approximates the mass in the range (66 μ) of the alphas.

The radioactivity of tracheal segments from some rats was also measured. (in the same way?) On the basis of these measurements the radiation dose to the epethelial linings of these trachea was calculated on the assumption that the alpha energy was expended in a cylindrical tube whose

inner diameter equalled the inner diameter of the trachea, 2 mm, and whose thickness equalled the average range of these alpha particles in water, 66 microns (9).

The lungs receive some radiation dosage from radon itself undergoing radioactive decay while in the lung. Dosage to the lungs from radon breathed into the lungs was calculated on the assumptions that the average lung volume was, in cubic centimeters, 4.4 percent of the rat weights in grams, that the average radon concentration in this volume was the same as in the air being breathed, and that the radon degradation products, through RaC', from radon decaying in the lungs, remained fixed in the lungs.

Volume ratio mean of lungs for rats is ~10? Is this realistic? For man it is much different thus one may question comparability!

Lung and tracheal dosages were measured in rats exposed to radon mixed with three different atmospheres.

1. The atmosphere contained particulate matter which approximated that of outdoor air in the vicinity of the laboratory.

2. The atmosphere contained nuclei produced by the electrical sparking of the brushes of a defective blower motor in the exposure chamber.

Is the differences in dosage as a function of dustiness are to be displayed (and in this case they seem to be significant) a probably better (and deliberate) source of dust should be used.

? how much (quantitatively) dustiness did (2) represent compared with (1). What were the Mg and σ values for the two dust distributions thus compared?

3. The air in the chamber was carefully cleared of its dust load before the radon was introduced.

Experimental results obtained when rats were exposed to radon in dusty atmospheres are shown in Table II. One can note that the average dosage per hour to the lungs from radon degradation products, 0.24 millirad, is some 57 times higher than estimated from radon itself plus only the radioactive daughters resulting from the radon decaying in the rat lung.

Measurements made on the tracheae of some of the exposed rats are also given. In Experiments 10-11, the atmosphere contained particulate matter which approximated that of outdoor air in the vicinity of the laboratory. The average tracheal dosage was 0.82 times the average lung dosage. In Experiments 12-13, the rats were exposed in air containing nuclei produced by the sparking of a defective blower motor in the exposure chamber. The nuclei were produced in the chamber some 18 hours before the rats were exposed. The average tracheal dosage was 0.46 times the average lung dosage.

Table I should appear here next for convenient reference

Table III represents the results of experiments in which rats were exposed to an atmosphere containing radon but largely cleared of suspended particulate matter before the radon was introduced by air filtration or prolonged settling of the material in the chamber air.

In Experiments 14 through 23 the air was not stirred during the animal exposure period. Simple removal of particulate matter from the chamber air reduced the average lung dosage by a factor of 5.1 compared with normally dusty air. In some of the experiments under these conditions dosage to tracheal epithelium was compared with dosage to the rat lungs as a whole. The tracheal dosage in five experimental rats averaged 7 times higher than the lung dose.

? because of turbulence in the trachea!

In Experiments 24 - 26 the chamber air was stirred with a fan preceeding and during the animal exposures. This procedure reduced the dosage from radon degradation products by a factor of 31 compared with clean, stagnant air, and a factor of 160 compared with air with a normal dust load.

Results with dogs

The gamma radioactivity produced by deposition of the radon degrada-

tion products in the lungs and tracheae of 14 dogs was also measured. These experiments had for their primary purpose measurement of the distribution of ventilation and perfusion in the various lobes of the dog lung. These experiments were carried out in collaboration with H. Rahn, and L. E. Farhi (10). Five dogs were exposed to radon and radon daughters contained in outdoor air with its normal dust load which had been introduced into the exposure chamber a few hours before the exposure. Nine additional dogs were exposed to an atmosphere in which the radon-daughter-carrying nuclei were generated artificially by a sparking motor. The tracheae were canulated in all experiments and the dogs anesthetized with sodium pentobarbital. The minute volumes of the first group of five dogs were measured during the experiment by passing air returning to the chamber through a gas meter. Results of these experiments are given in Table IV. Respiratory rates of Dogs 1, 2, and 3 averaged 20, 30, and 15 respectively during the experiment. Dog 5, under very deep anesthesia, respired about 1 per minute. Respiratory rates for the other animals were not recorded.

No dog data with ~~wet~~ filtered air

Radon daughter product deposition in man.

The fraction of the inhaled radon daughter products retained by two human subjects was measured for chamber air with a normal dust load and by one subject for air cleaned of particulate matter. The general principle of the experiment was first to sample for radon daughter radioactivity in the air to be breathed by the subject, second with the subject breathing chamber air to collect and measure the radon daughter activity of the air exhaled by the subject, and finally, again sample the air breathed by the subject. Reduced pressure behind the millipore paper used for removing degradation products from exhaled air increased the flow of air through the filter so that the subject could breathe under essentially physiological conditions. The apparatus is shown in Figure 1.

The results are given in Table V. The average retention of the daughter products in air containing normal atmospheric dust was 25 percent. The average retention of the daughter products in filtered air was 75 per cent. A neoprene balloon, used as an artificial lung, gave essentially zero retention in air containing normal atmospheric dust.

how does the amount of Ru daughters present compare to the hazard of air conditioning vs. nat. air would vary as product of amt present and amt retained

what did the neoprene balloon give for retention with filtered

This [illegible] be titled: Average [illegible] as calculated from gamma measurements

TABLE II. Average Radiation Dosages to Lungs and Tracheae of Rats Breathing Radon Daughters Carried on Atmospheric Dust at Concentrations Equivalent to Equilibrium with 10^{-11} curies/liter Radon

Exp. No.	Wt. (gm)	Measured average dosage to lungs erg/gm/hr	Measured average dosage to lungs millirad/hr	Measured average dosage to tracheae erg/gm/hr	Measured average dosage to tracheae millirad/hr
1-9	190(avg)	.022±.005	.22		
10	184	.036	.36	.033	.33
11	185	.033	.33	.024	.24
12	183	.027	.27	.010	.10
13	189	.024	.24	.013	.13
Estimated dosage from radon gas undergoing radioactive decay in the lungs.		.00042	.0042	.00033	.0033

condition (1)

condition (2)

Experimental conditions.

The rats in Experiments 1-11 were exposed in air containing particulate matter which approximated that of outdoor air in the vicinity of the laboratory. The diffusion coefficient of the radioactive dust was about 4.8×10^{-6} cm^2/sec, as determined by measuring the deposition of the dust in tubes. The rats in Experiments 12 and 13 were exposed in air containing nuclei produced by the sparking of a defective blower motor in the exposure chamber. The nuclei were produced in the chamber some 18 hours before the rats were exposed. The radioactive dust had a diffusion coefficient of about 9×10^{-7} cm^2/sec.

? How

What is the interpretation of the difference in diffusion coefficient?

The radon level in the chamber was about 22×10^{-9} curies/liter. For rats 1-9, 12, 13, the daughter product level in the air was between 90 and 95% of its potential equilibrium value with the radon. For Rats 10 and 11, the daughter product level was 56% of its equilibrium value, the remainder of the daughter products being on the walls of the chamber. The lung activities were of the order of 15000 cpm. Tracheal activities were 100 cpm above the background, which averaged 120 cpm.

Method for determining dosage

The NaI well-type counter used to count the rats' lungs was calibrated to measure the alpha radioactivity in the lungs by counting the daughter product gamma activity of a millipore filter after alpha measurements had been made on the filter with an alpha scintillation counter. The radioactive millipore sample was prepared by drawing a liter of chamber air containing radon and its daughter products in equilibrium through it. Its absolute alpha disintegration rate was obtained by comparing its counting rate with that of a calibrated uranium foil which was the same size as the millipore. The alpha self-absorption in the millipore filter paper was 3 percent (7). After the alpha activity of the millipore was measured, it was inserted into a test tube, and dissolved in acetone so that it occupied approximately the same volume as the rats' lungs. By extrapolation, the α/γ ratio on the millipore paper was obtained at 60 minutes after collection of the air sample. From a knowledge of the γ spectrum emitted by the daughter products, it was calculated that this was equal to the α/γ ratio of an infinite sample, i.e., the rat's lung. This was verified experimentally by comparing the α/γ ratios of grab millipore samples at 60 minutes decay and infinite millipore samples at 0 decay. The gamma

activity of a tube containing some uranium ore was read at the same time gamma measurements were made on the millipore paper and served as a secondary standard for some of the experiments. The alpha energy imparted to the lungs was obtained from the average alpha energy per alpha disintegration, which is 7.58 Mev. The calibration method has been previously discussed in detail (7).

TABLE III. Average Radiation Dosages to Lungs and Tracheae of Rats Breathing in Cleaned Air Containing 10^{-11} curies/liter Radon.

Exp. No.	Rat Wt. (gm)	Dtr. prod. concentration c/l x 10^{11}	Measured average dosage to lungs erg/gm/hr	Measured average dosage to lungs millirad/hr.	Measured average dosage to tracheae erg/gm/hr	Measured average dosage to tracheae millirad/hr.
14-18	197 (avg)	.18	.0045±.001	.045		
19	201	.44	.0094	.084	.049	.49
20	182	.23	.0049	.049	.020	.20
21	200	.33	.0053	.053	.035	.35
22	198	.21	.0031	.031	.035	.35
23	192	.23	.0018	.018	.013	.13
24-26	184	.022	.00015±.00003			
Estimated dosage from radon gas and disintegration products of radon molecules decaying in lungs.			.00042	.0042	.00033	.0033

During Experiments 24-26 the air in the exposure chamber was stirred vigorously with a fan. The air was not agitated during Experiments 14-23. The fanning of the air caused most of the daughter products to be deposited on the walls of the exposure chamber.

TABLE IV. Average Dosages to the Lungs and Tracheae of Cannulated Dogs Breathing in Uncleaned Air Containing 10^{-11} Curies/Liter Radon in Equilibrium with Its Daughters

Dog	Wt Kg	Min Vol/kg cc/min/kg	Avg millirad/hr to lung	Avg millirad/hr to trachea
1	13.3	233	.032	.21
2	8.35	336	.047	.35
3	9.54	178	.036	
4	9.6		.037	.48
5	8.48	41	.024	.062
Avg. 9 dogs (6-14)	7.0		.030	.18

average of 1- [illegible] for comp[illegible] with 6-1

The counter used to measure the gamma activity of the dogs' lungs and tracheae was the Texaco well-type Geiger counter, type GR, manufactured by Welch-Allyn, Inc. The lobes of the lung were counted individually and then added to give the total lung activity. The counter was calibrated by the α/γ ratio method described in Table II. The radon level in the chamber was 31×10^{-8} curies per liter. Lung activities were of the order of 35000 cpm at 0 decay time; tracheal activities ranged between 200 and 1700 cpm. The background on the counter was 500 cpm. The tracheal segments counted were about 1 cm in diameter and between 8 and 11 cm long.

Dogs 1-5 breathed daughter products carried on ordinary atmospheric dust. Dogs 6-14 breathed daughter products carried on nuclei produced from the sparking of a blower motor in the chamber.

TABLE V. Results of Human Retention Experiments

Subject	Tidal Volume Liters	Percent Retention
(a) Daughter products on atmospheric nuclei		
1	1.3	27
1	1.1	23
1	1.1	25
2	1.0	25
2	0.72	22
2	1.5	30
Artificial lung		0
(b) Daughter products in filtered air		
1	1.5	72
1	1.5	78

Discussion

From the human exposure data given in the previous section, and assuming the long biological half-life found for rats also holds for human beings, one can calculate radiation dosage to the human pulmonary system under those exposure conditions for which the data were obtained.

For radon daughter products in normally dusty air, notation and assumptions are as follows:

V_m = Minute volume -- 10 liters/minute 1.

Airborne RaA through RaC' in equilibrium 2.

$C_d^{(1)}$ = Concentration of each daughter -- 1×10^{-11} curie/liter (1×10^{-8} μc/cc) 3.

R = Fractional retention -- .25 4.

W_e = Weight of lungs -- 1000 gm 5.

All radioactivity retention occurs in lungs 6.

E_α = the energy in Mev due to α radiation from complete radioactive decay of RaA, RaB, RaC, and RaC', each at an initial activity of 1μμ curie, where disintegration constants are given in units of min.$^{-1}$ is 7.

$$2.2 \times \left[\left(\frac{6.00}{\lambda_A} + 7.68\left(\frac{1}{\lambda_A} + \frac{1}{\lambda_B} + \frac{1}{\lambda_C} + \frac{1}{\lambda_{C'}}\right)\right)\right] = 1.277 \times 10^3$$

D_e = the average α radiation dose to the lungs in millirad units per hour will then be

$$\frac{C_d \times 10^{12} \times V_m \times R \times 60 \times E_\alpha \times 1.6 \times 10^{-6} \times 10^3}{W_e \times 100} = 0.029$$

1168

where the numerical values in order in the numerator are the conversion factor from curies to micromicrocuries, from hours to minutes, from Mev to ergs, from rad to millirad, and in the denominator from rad units to erg/gram.

For radon daughter products in very clean air, using the same assumptions except for a three times greater retention of 75 percent, the lung dosage is .087 millirad per hour.

These calculations assume radioactive equilibrium between the airborne daughter products. The formula will apply also to those situations occuring in practice where the daughter products are not in equilibrium with each other if the daughter product air sample whose alpha activity is to be determined for the purpose of obtaining C_d is allowed to decay one hour from the mid-point of the collection time (which should not exceed 10 minutes). The activity measured at 60 minute decay is then extrapolated back to zero time assuming daughter product equilibrium. It has been shown that the calculated lung dosage based on this treatment of the air measurements is fairly independent of the actual relative daughter product concentrations in the air (7).

1168670

$10^{-11}\left(\frac{e}{\ell}\right) 10^{10}\left(\frac{\mu e}{e}\right) \frac{1}{10^3}\left(\frac{\ell}{cc}\right) = 10^{-8}\ \mu e/cc$

On the basis of our experimental results the average radiation dose to the lungs as a whole, breathing radon daughters at a level of 1 x 10^{-11} curies per liter each for RaA and RaC' in normally dusty air, would be 168 x .029 = 4.95 millirad per week of 168 hours. The experimental breathing rate was about 10 liters per minute. The additional contribution in lung dosage from an equilibrium amount of radon itself present in the air would be small.

Since this value of 1 x 10^{-11} curies per liter (1 x 10^{-8} microcuries/cc) is also the maximum permissible level for radon for continuous exposure in the latest published recommendations of the National Committee on Radiation Protection (2) it is instructive to see how the human lung exposure figures estimated from our experiments correspond to the permissible tissue exposures recommended in the same committee publication. They recommend that human tissue dosage be limited to 0.3 rep per week for β and γ radiation, and that the maximum permitted tissue dosage from alpha radiation be 20 times lower, 15 millirep per week, to allow for its greater relative biological effect. Since 100 millirep equal 93 millirad, this

Now RBEx set at 10 not 20 - per ICRP/3/4

allowed 15 millirep per week is about three times the experimentally estimated average lung dosage for data presented here.

Average radiation dosage to the epithelial lining of the larger bronchi is more difficult to estimate from experimental data. Extrapolation of the results of the dog experiments to human subjects suggests that this dosage may reach ten times the dosage to the lung as a whole.

Since even in air containing a considerable amount of large particle dusts, the radon daughters seem to be largely deposited on small particles, the deposition of radon daughters still appears to be largely by diffusion. Therefore, the average dose to the bronchial tubes probably does not depend very strongly on the breathing pattern of the individual being exposed as long as the air flow through the lung passageways is laminar. In one experiment the activity deposited in plastic tubes approximately 2 mm in diameter was measured as a function of minute volume. An average decrease of minute volume of 59 percent decreased the activity deposited in the tube by only 29 percent. Accordingly, the tracheal dosages reported in this paper may give a fair indication of the dosages imparted to tubes of

Then filtered air leads to MP exposure with 10 [illegible] but $\frac{2 \times 10^4}{1440}$ = 139 so aver 40% exposure w. fil air

1166476

similar size in the human respiratory tract. They suggest that average radiation dose to the human bronchi may be a few times higher than to the lungs as a whole, and therefore may reach or exceed 15 millirep per week.

The experimental results reported here therefore suggest that a maximum acceptable level of radon in equilibrium with its daughters of 1×10^{-11} curies per liter is consistent with a maximum allowed organ dose of 15 millirep per week for alpha radiation, providing this figure is interpretable to allow an average radiation dosage to bronchial epithelium somewhat higher than to lung tissue as a whole.

It is likely that future recommendations of the Committee on Radiation Protection will be in rad units and will use a factor of ten rather than twenty as an allowance for the greater biological effect of alpha radiation compared with beta and gamma radiation. This will increase the allowed organ dose to 30 millirad per week for alpha radiation and the acceptable level for radon to 2×10^{-11} curies per liter (3). Since the present data confirm suggestions that the primary radiation hazard to the lung is from the radon daughters rather than radon itself it appears reasonable to interpret this level for practical purposes as a statement that the continuous airborne

daughter concentration, RaA through RaC', shall not exceed that in equilibrium with 2×10^{-11} curies radon per liter. This, in effect, will permit higher radon levels providing, as is often the case under practical exposure conditions, the daughters are present in substantially less than equilibrium amounts. This reduction in daughter concentration compared with radon will ordinarily be produced by ventilation, the radon being swept out of the exposure area before RaB through RaC' have built up toward equilibrium levels.

In addition our data indicate that, under some conditions, the radon daughters present in air can be greatly reduced in concentration by rigorous cleaning and continual recirculation of the air, even though radon itself is not removed or diluted. Whether any practical application can be made of this technique for reducing daughter levels is not known. Such daughters as remain in suspension, however, may be more than normally hazardous because of a greater retention in the human respiratory system.

All the previously discussed tolerance calculations were on the basis of continuous exposure to an atmosphere containing radon. In practice, the maximum acceptable concentration during a 40-hour week would be higher by a

factor of two if the recommendations of the National Committee on Radiation Protection are followed, and if no further exposure occurs away from work.

The fundamental assumption upon which these tolerance calculations are based, that the maximum allowable radiation dosage to the lung should be 0.3 rad per week, β, γ radiation or a lesser amount of α radiation by a factor of ten or twenty, has not been demonstrated specifically for human lung tissue. Therefore, the data presented here have by no means constituted proof that exposure even to substantially larger concentrations of radon and radon daughters will necessarily be followed by objective evidence of damage to the human being undergoing such exposure.

Summary

Rat exposure studies indicate that the biological half-life of airborne radon daughters (the active deposit) is long compared with the physical life. Dog exposure studies indicate that the lining epithelium of the large bronchi receives an average radiation several fold higher than the lung as a whole. Human retention studies show a retention in the respiratory tract

of about 25 percent of radon daughters in air with a normal dust load, and about 75 percent of daughters from very clean, dust-free air.

clean air worse? or better than normal air

It is concluded that radiation exposure to the human lungs from breathing an atmosphere containing radon is usually primarily due to radon daughters rather than from radon itself. It is further concluded on the basis of experimental data presented here that the maximum allowable air concentration of radon currently recommended by the National Committee on Radiation Protection of 1×10^{-11} curies radon per liter (1×10^{-8} curies/cc) for continuous 24 hours exposure is consistent with the published assumption of this committee that no organ should receive a dose of alpha radiation of more than 15 millirep per week. It is suggested, however, that these recommendations be interpreted in terms of the concentration of airborne radon daughters rather than of radon itself. This would permit higher radon concentrations under conditions where radon daughter concentrations were kept low by ventilation or other procedures. Reference is made to a proposed increase in the acceptable weekly alpha radon dose by a factor of slightly greater than two. This would allow a similar increase in the permissible air concentration of radon and radon daughters.

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Legends for Figure

Fig. 1 Experimental arrangement for human inhalation experiment.

A) Exposure chamber. B) Neoprene stopper. C) Respiratory check valve. D) Mouthpiece. E) Manometer. F) Gas meter. G) Flutter valve. H) Millipore filter holder. I) Vacuum pump. J) Gas meter.

The vacuum pump operated during the entire run. When the subject did not expire through the check valve, room air was drawn through gas meter (F) and through the millipore filter. When the subject exhaled, the flutter valve (G) was closed and the subject's air was drawn through the millipore filter by the vacuum pump. The pressure at the outlet end of the respiratory check valve was about -1 cm H_2O because of the flow of air through meter (F). The chamber was maintained at about -3 cm to insure that no air would be drawn by the vacuum pump directly from the chamber.