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Formerly Utilized Sites Remedial Action Program (FUSRAP)

ADMINISTRATIVE RECORD

for Maywood, New Jersey

U.S. Department of Energy

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State of New Jersey 2 26 PM '94
Department of Environmental Protection and Energy
Division of Environmental Safety, Health and Analytical Programs
CN 415
Trenton, NJ 08625-0415

Jeanne M. Fox
Acting Commissioner

Gerald P. Nicholls, Ph.D.
Director

January 7, 1994

Paul Giardina
USEPA Region II
26 Federal Plaza
New York, NY 10278

Dear Paul:

I am aware of your interest and efforts in regard to clean-up levels for radioactively contaminated sites. The purpose of this transmittal is to share with you the work we have done in New Jersey to date on the development of clean-up levels for soils containing technologically enhanced levels of naturally occurring radionuclides.

In 1993 the Industrial Site Recovery Act (ISRA) or S-1070 was enacted into law in New Jersey. This law establishes cleanup criteria for contaminated sites in New Jersey. The criteria for cleanups are now based on an excess lifetime cancer risk of one in one million (10^{-6}) or on regional natural background levels if the risks associated with them are greater than 10^{-6}. This has had a significant impact on the way cleanup standards are to be developed for sites contaminated with radioactive materials. Because background levels of radiation will result in a lifetime cancer risk of greater than 10^{-6}, the only viable option is to use the "regional natural background level" as the cleanup criteria.

Consequently, my Bureau, the Bureau of Environmental Radiation, has been developing cleanup criteria for residential and nonresidential uses for the radionuclides present at New Jersey sites. The methodology being used to derive these numbers is outlined in detail in Enclosure 1 (residential criteria) and Enclosure 2 (non-residential criteria) and summarized below. Our premise in developing these criteria is that once the site is remediated to these levels, it can then be released for any residential or nonresidential use, as the case may be.

Standard Development

To follow the provisions of S-1070, we have had to analyze the radiation from varying levels of contamination in comparison to "natural background" radiation levels. We have considered four pathways: 1) external gamma radiation, 2) indoor radon, 3) internally deposited radionuclides and 4) ground water. For external gamma background, we are currently using terrestrial background radiation data as reported in NCRP Report No. 94. Terrestrial background was the most appropriate parameter because contaminated soil is part of the "terrestrial" component. Because natural background varies from place to place, a statistical approach was needed. To accommodate such variation, natural background for terrestrial gamma is being defined as one standard deviation from the mean value of 28 mrem/yr. Based on the distribution of the NCRP data, one standard deviation is approximately 6 mrem/yr. Therefore, based on nationwide background gamma levels, contamination on site cannot contribute an incremental external gamma dose of greater than 6 mrem/yr. New Jersey specific data still needs to be examined.

For the radon pathway, natural background was determined by converting state-wide measurement data to lognormal form and calculating the standard deviation of the resulting distribution. The geometric mean for radon in the inner coastal plain is 1.35 pCi/L, with a standard deviation of 2.94 pCi/L Therefore, incremental cleanup levels are based on meeting a 3 pCi/L incremental indoor radon level.

For internally deposited radionuclides we considered and summed crop ingestion, direct soil ingestion, inhalation from resuspended dust, and groundwater consumption component. "In the body" background was also determined using NCRP Report No. 94. According to this report, the average annual dose in the United States from ingesting and inhaling radioactive materials is 40 mrem/yr. To provide for natural variation, a 25% increment was established, resulting in an allowable increment of 10 mrem/yr from internally deposited radionuclides.

Radionuclide standards for the groundwater pathway are established in the Groundwater Quality Standards (N.J.A.C. 7:9-6) and are based on the prevailing Safe Drinking Water Act regulations in N.J.A.C. 7:10-1 et seq.. These standards are still applicable under the provision of S-1070. The standards for radionuclides are 4 mrem/yr for beta and gamma emitters and 5 pCi/L for alpha emitters.

In order to determine the soil concentrations that would result in these incremental background doses, we have reviewed dose conversion factors (DCF) using the available literature for each pathway. The DCF is the dose received from a given pathway for each pCi/g of a radionuclide in the soil. The allowed soil concentration for a radionuclide is calculated by dividing the incremental dose for each pathway by the DCF. The most restrictive pathway was then used to determine the acceptable soil concentration. This method was followed for each individual radionuclide subchain. However, in order to account for ingrowth of progeny, certain subchains had to be combined. The sum of the fractions rule was used to determine the acceptable soil concentrations considering this ingrowth. From this analysis, the need for clean cover to achieve acceptable gamma radiation levels became evident.

In addition, since most naturally occurring radionuclides have long half-lives, we could not assume that the covered material would remain undisturbed for the length of time required for these radionuclides to decay to allowable levels. For this reason, we also analyzed a "disruptive scenario". This scenario assumes that a basement for a house or building would be excavated on the contaminated site and that the excavated material would be mixed and brought to the surface. As necessary we adjusted the allowed concentration levels downward to account for the impacts of the disruptive scenario. To achieve adequate mixing, the need to restrict the thickness of the contaminated zone - for near surface burials - arose.

Taking all of these factors into account, Table 1 displays the allowed incremental (in addition to what is present in natural soil) soil concentration levels for certain nuclides of interest.

Table 1

Preliminary
Allowed Incremental Soil Concentration Levels
To Meet Established Background[1]
(pCi/g)

	Residential Use	Nonresidential Use
Ra-226	3	6
Pb-210	3	6
Th-232	3	6
Ra-228	3	6
Th-228	3	6
U-238	4	7

[1] Assumes at least one foot of cover placed on material and thickness of contaminated zone less than about 4 feet (for near surface burial).

The nonresidential use levels also meet the incremental doses outlined above: 6 mrem/yr external gamma, 3 pCi/L indoor radon, 10 mrem/yr internal and 4 mrem/yr groundwater. However, in deriving the nonresidential allowed soil concentration, we used different occupancy factors, and eliminated the child soil ingestion and crop ingestion pathways. Preliminary results indicate that the allowed concentration levels for the nonresidential scenario to be about twice that for the residential.

I would emphasize that these cleanup numbers for both residential and non-residential use scenarios are preliminary. We are in the process of reevaluating and refining the dose conversion factors and certain assumptions used in deriving the clean-up levels, however, the "background" approach and the pathway analysis used will likely remain as is.

We are aware that remediating sites contaminated with large volumes of radioactive material to within the levels required by S-1070 through removal to off-site radioactive waste disposal facilities may result in costs that are beyond the financial resources of the responsible party. Therefore, we are investigating potential alternatives to this method of disposal such as on-site mixing, use of these materials in road construction, removal to industrial landfills, deeper burial on-site or a combination of these options.

I hope this material and effort we have put into this is of some use to you. If you have any questions or suggestions, please feel free to write or call me on (609) 987-2101.

Sincerely,

Bob Stern

Bob Stern, Ph.D., Chief
Bureau of Environmental Radiation

Enclosures

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ENCLOSURE 1

12/15/93

OBJECTIVE: TO ESTABLISH SCIENTIFICALLY CREDIBLE CLEANUP STANDARDS FOR DIFFUSE NATURALLY OCCURRING RADIOACTIVE MATERIALS (NORM).

Bob Stern, Chief
Bureau of Environmental Radiation
(609) 987-2101

Naturally Occurring Radioactive Material (NORM) Waste Disposal

BACKGROUND OF NEW JERSEY NORM DISPOSAL PROBLEM

- substantial volumes of diffuse NORM generated and currently being stored
- potentially significant public health risks if uncontrolled
- Envirocare facility will accept materials but cost is significant
- need to explore other remedial options
  - onsite mixing and concentration reduction
  - disposal at industrial landfills

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<u>CLEAN-UP STANDARDS</u>

- recently enacted NJ law - ISRA (Industrial Site Recovery Act)

  - set State clean up standards to achieve either:

    - 10^{-6} lifetime risk level, or

    - meet "regional background" levels

  - risk level impractical for NORM wastes, must use "background" criteria.

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Exhibit 1: Radioactive Decay Chains Included in HEAST Tables 4A and 4B*

Principal Decay Chain	Subchain[a]	Members[b]	Half-life[c]
Uranium-238	U-238 + D	U-238	4.468E+09 Y
		Th-234	2.410E+01 D
		Pa-234	1.170E+00 M
	U-234	U-234	2.445E+05 Y
	Th-230	Th-230	7.700E+04 Y
	Ra-226 + D	Ra-226	1.600E+03 Y
		Rn-222††	3.823E+00 D
		Po-218	3.050E+00 M
		Pb-214	2.680E+01 M
		Bi-214	1.990E+01 M
		Po-214	1.637E-04 S
	Pb-210 + D	Pb-210	2.226E+01 Y
		Bi-210	5.013E+00 D
		Po-210	1.384E+02 D
	Pb-206	Pb-206	[Stable]
Uranium-235	U-235 + D	U-235	7.038E+08 Y
		Th-231	2.552E+01 H
	Pa-231	Pa-231	3.726E+04 Y
	Ac-227 + D	Ac-227	2.177E+01 Y
		Th-227 [99%]	1.872E+01 D
		Ra-233	1.143E+01 D
		Rn-219	3.960E+00 S
		Po-215	1.778E-03 S
		Pb-211	3.610E+01 M
		Bi-211	2.130E+00 M
		Tl-207	4.770E+00 M
	Pb-207	Pb-207	[Stable]
Thorium-232	Th-232	Th-232	1.405E+10 Y
	Ra-228 + D	Ra-228	5.750E+00 Y
		Ac-228	6.130E+00 H
	Th-228 + D	Th-228	1.913E+00 Y
		Ra-224	3.620E+00 D
		Rn-220	5.561E+01 S
		Po-216	1.460E-01 S
		Pb-212	1.064E+01 H
		Bi-212	6.055E+01 M
		Po-212 [64%]	2.980E-07 S
		Tl-208 [36%]	3.053E+00 M
	Pb-208	Pb-208	[Stable]

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OVERALL APPROACH TO STANDARD SETTING

- Unrestricted site use
  - Resident scenario

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- Estimate pathway dose conversion factors (DCF) for range of radionuclide subchains and pathways
  - for radon; picocuries per liter in air per picocurie per gram of radionuclide in soil
  - for gamma exposure; effective dose equivalent per picocurie per gram of radionuclide in soil
  - for all other internal intakes; committed effective dose equivalent per picocurie per gram of radionuclide in soil
  - residential site use
  - non-residential site use

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- Compare to an "allowable background" incremental dose
- Determine allowed soil concentration
  - Allowed soil concentration increment= $\dfrac{\text{allowed background increment}}{\text{DCF}}$ (1)
  - Add natural background to allowed increment to determine total allowed activity level

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Dose Conversion Factors

RADIATION DOSES (TERMINOLOGY)

...osure	Dose	Dose equivalent	"Effective" dose equivalent	"Committed" dose equivalent or Committed Effective dose equivalent (CEDE)	"Lifetime" dose* equations
...iders ...rgy ...rption ...ir	considers energy absorption in tissue	considers type of radiation	considers health impacts from different organs/tissues	considers internal retention of radionuclides from a single intake	considers dose over lifetime from repeated yearly intakes

More representative of actual risk ------------------------→

←------------------------ Less representative of actual risk

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... short effective half-lives, lifetime dose = 50 x CEDE. For long effective half-lives, ...etime dose = 25 x CEDE. (See Derivation of Lifetime Risks for Repeated Intakes)

Primary Guides for Assessed Dose to Individual Workers

The objective of the dose limitation system is both to minimize the risk of stochastic effects and to prevent the occurrence of non-stochastic effects. The primary guides are boundary conditions for this system. The principles of justification and optimization serve to ensure that unnecessary doses are avoided and that doses to most workers remain significantly below the limiting values specified by the primary guides.

With respect to stochastic effects, the dose limitation system has been designed with the intent that the level of risk associated with the limit be independent of whether irradiation of the body is uniform or non-uniform. The critical-organ approach of previous guidance (FRC 1960) is replaced with the method introduced by the ICRP (ICRP 1977), which utilizes a weighted sum of doses to all irradiated organs and tissues. This sum, called the "effective dose equivalent" and designated H_E, is defined as

$$H_E = \sum_T w_T H_T \,, \qquad (1)$$

where w_T is a weighting factor and H_T is the mean dose equivalent to organ or tissue T. The factor w_T, normalized so that $\sum_T w_T = 1$, corresponds to the fractional contribution of organ or tissue T to the total risk of stochastic effects when the entire body is uniformly irradiated.* H_E thus reflects both the distribution of dose among the various organs and tissues of the body and their assumed relative sensitivities to stochastic effects. The primary guide for assessed dose to individual adult workers, for the purpose of protection against stochastic effects, is 5 rem (50 mSv) effective dose equivalent in a year (Recommendation 3, Appendix A).

Weighting Factors

Organ/tissue	w_T
Gonads	0.25
Breast	0.15
Red Marrow	0.12
Lungs	0.12
Thyroid	0.03
Bone Surface	0.03
Remainder†	0.30

Additional primary guides for assessed dose to individual adult workers have been established for the purpose of protection against non-stochastic effects. These guides, chosen below the assumed threshold levels for such effects, are 15 rem (150 mSv) dose equivalent in a year to the

$$H_T \leq 15 \text{ rem } (150 \text{ mSv}) \tag{2c}$$

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for the lens of the eye.

Primary Guides for Control of Intake of Radionucludes in the Workplace

Radionuclides enter the body through inhalation and, normally to a lesser extent, through ingestion. The principal method of controlling internal exposure to radionuclides is to contain radioactive materials so as to avoid any such intake. For situations where this is not achievable, the guidance (Recommendation 4, Appendix A) specifies primary guides for control of the workplace.

The intake of certain long-lived radionuclides may result in the continuous deposition of dose in tissues far into the future. The primary guides for control of the workplace are therefore expressed in terms of the sum of all doses projected to be received in the future from an intake in the current year. This sum, by convention taken over the 50-year period following intake,* is known as the "committed" dose. The committed effective dose equivalent, $H_{E,50}$, is defined by analogy to equation (1) as

$$H_{E,50} = \sum_T w_T H_{T,50} . \tag{3}$$

The committed dose equivalent to tissue or organ T, denoted $H_{T,50}$, is the total dose equivalent deposited in T over the 50-year period following intake of the radionuclide. For radionuclides that are present in the body for weeks or less, because of either short physical half-life or rapid biological elimination, the committed dose equivalent may be regarded as a single contribution to the annual dose equivalent. For very long-lived radionuclides that remain within the body indefinitely, the dose equivalent may accumulate at a nearly constant rate over the entire balance of a worker's lifetime.

To limit the risk of stochastic effects, the *primary guides for control of the workplace* specify that the committed effective dose equivalents from the intake of all radionuclides in a given year, $H_{E,50}$, plus the effective dose equivalent from any external exposure in that year, $H_{E,ext}$, should not exceed 5 rem (50 mSv), i.e.:

$$\bar{H}_{E,50} + H_{E,ext} \leq 5 \text{ rem} . \tag{4a}$$

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*50 years reflects the arbitrarily-assumed remaining lifetime of a worker, rather than the maximum span of employment.

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Effect of Continuous Intake

$$Hc_T(t) = H_{T,50} \frac{(t - 1/\lambda_e (1-e^{-\lambda_e t}))}{1-e^{-50\lambda_e}}$$

T denotes target organ

Total Dose Accumulated over 50 years = $\Sigma_T W_T Hc_T (50)$

Look at limiting cases:

$\lambda_e \to o$ $\quad$ $H_c (50) = 25 \times H_{T,50}$

$\lambda_e \to \infty$ $\quad$ $H_c (50) = 50 H_{T,50}$

$\lambda_e \to o$ $\quad$ H_c (effective) $= 25 \times \Sigma_T W_T H_{T,50} = 25 \times$ CEDE

$\lambda_e \to \infty$ $\quad$ H_c (effective) $= 50 \times \Sigma_T W_T H_{T,50} = 50 \times$ CEDE

Lifetime risk = 5×10^{-7} (health effects per mrem) x H_c (effective)

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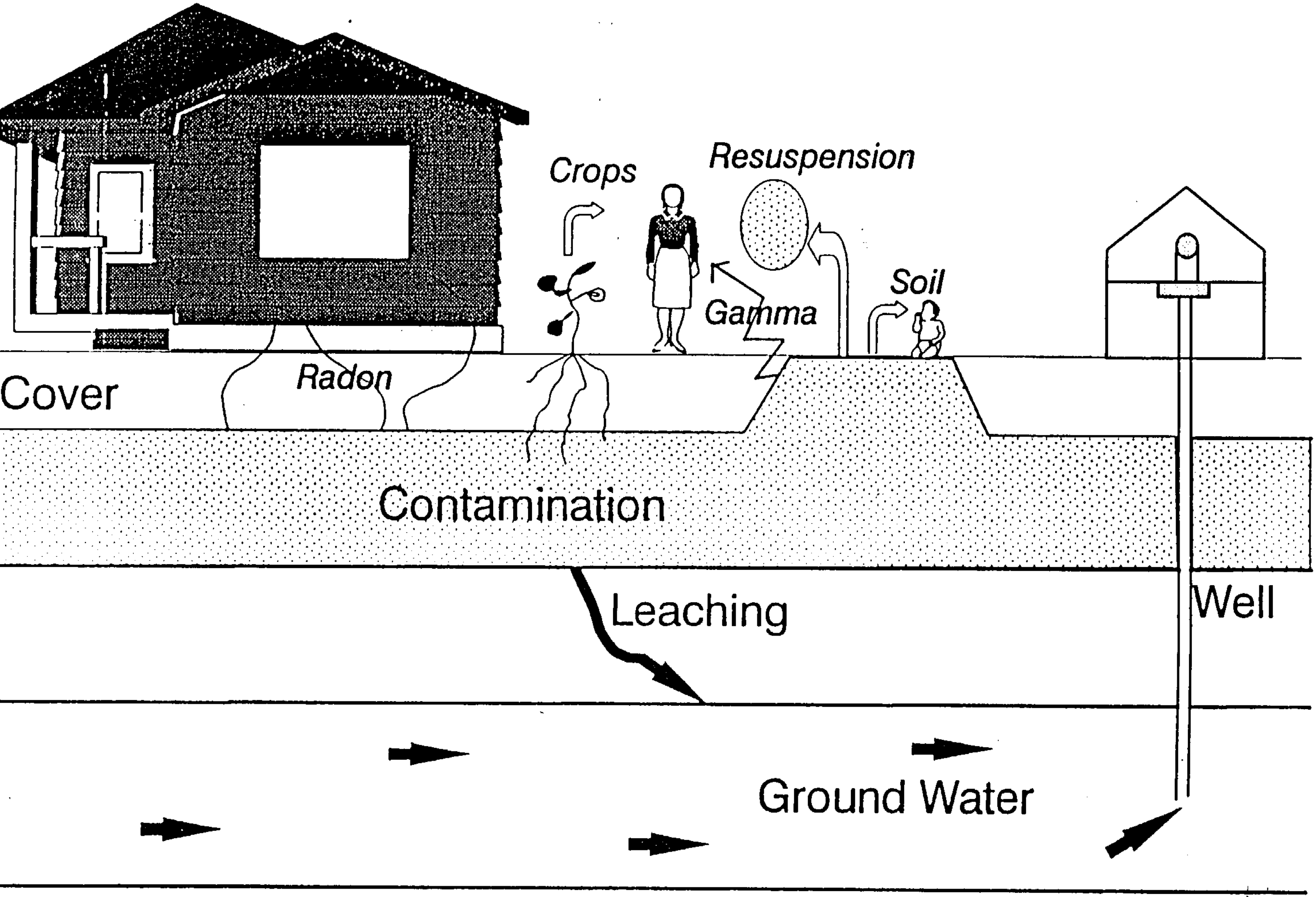
PATHWAYS



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DOSE/PATHWAY ASSESSMENT

- The Dose Assessment Activity Includes:

- Exposure Pathway Analysis

  * For each radionuclide and pathway, determine the resulting dose per unit of radioactivity left in the soil (dose conversion factors)

  * For unrestricted use standards, the exposure pathways being evaluated include:

    - Radon Inhalation
    - External Gamma
    - Soil Ingestion
    - Crop Ingestion
    - Soil Resuspension/Inhalation
    - Water Ingestion

  * Sum the last four pathways to estimate total internal dose (exclusive of radon)

  * Results in three groupings; radon, gamma, internal

- Use The Dose Conversion Factor For Each Radionuclide and an Allowed Background Level to Determine The Allowed Residual Soil Radioactivity Level

- Some Specific Radionuclide Subchains Involved; Uranium-238, Radium-226, Thorium-228, Lead-210 Th 232, and Ra 228

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DOSE CALCULATIONS

A: See Papers

CT SOIL INGESTION:

Dose (mrem/yr) = C in soil (pCi/gm) x Ingestion rate (gms/day)

x Ingestion dose factors from tables (mrem/pCi)

LATION:

Dose (mrem/yr) = C (pCi/gm) x air to soil ratio (gms/m^3)

x air intake (m^3/yr) x Inhalation dose factors from tables (mrem/pCi)

x cover and depth factors (see RESRAD manual: pg. 136)

TATIVE INTAKE (ROOT UPTAKE; NO AIR DEPOSITION):

Dose = C (pCi/gm) x B_{iv}; soil to vegetable transfer factor

x vegetative intake (Kg/yr) x 1000 gms/Kg x Ingestion dose factor (mrem/pCi) x depth factor

where depth factor* = $1 - \frac{\text{cover depth}}{\text{maximum root depth}}$

when cover depth is less than maximum root depth

and cover depth + thickness of contamination is greater than maximum root depth

IDWATER (See Attachment)

RESRAD manual; Pgs. 140-146

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TABLE 1: DOSE CONVERSION FACTORS; DOSE PER 1 PCI/GM IN SOIL

Thorium 230, Radium 226, Lead 210 Subchains (daughters in equilibrium)

Isotope	External Gamma Radiation (a)	Direct Soil Ingestion (b)	Crop Ingestion (b)	Air Resuspension (b)	Water Ingestion (b)	Indoor Radon Inhalation (c)
Thorium 230(Y)	<<1(1)	.003(3) .004(10) .04 .04(9)	<<1(3) .03(4) .1 .1(6) .02(10) .12(15)	0.09(4) .1 0.11(6) 0.08(10) 0.24(15)		
Radium 226		.10(9)	.68(6)	.01(4) .01(15)	0.4(13)	
Rn 222(radon)						1.0(5) 1.25(18)
Po 218						
Pb 214	.8(1) 1.2(4) 1.5(9) 1.3(12)					
Bi 214	7.2(1) 6.8(4) 9.5(9) 9.7(12)					
Po 214	- - - - -					
Subchain dose	8.0(1) 8.0(4) 10.9(9) (10) 11.0(12) 19.3(14) 15.4(15)	0.4(3) 0.1(9) 0.6(10) (.3)	.5(3) .03(4) (.2) .68(6) .95(10) 13.4(11) .5(15)	.01(4) .01(15) <<1(6)	0.4(13)	

Residential Use: Impaction Range (I) = .18 → .40
No cover; use .25, $C = \frac{10}{.25} = 40$
1' cover use $.2 \times \frac{2}{3}$, $C = \frac{10}{.07} = 140$

Non-Res Use: 0 cover; C = 10/.15 = 66 (I)
1' cover; no path

	0' cover	1' cover
Gamma	C = .6 (G)	C = 6 (G)
Ing	C = 10/.3 × 1.68 = 34 (I)	C = 10/.4 × 2 = 50 (I)
Water	C = 4/.4 × 2 = 20 (GW)	C = 4/.4 × 2 = 20 (GW)

Residential Use

0 cover	1' cover
C = 10/2.7 × 1.68 = 6.2 (I)	C = 10/1.7 × 1.68 = 10 (I)
C = 4/.4 = 40 (GW)	C = 40 (GW)
C = 6/10 = .6 (G)	C = 6 (G)

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TABLE 1: DOSE CONVERSION FACTORS; DOSE PER 1 PCI/GM IN SOIL (CONTINUED PAGE 2)

Thorium 230, Radium 226, Lead 210 Subchains (daughters in equilibrium)

Isotope	External Gamma Radiation (a)	Direct Soil Ingestion (b)	Crop Ingestion (b)	Air Resuspension (b)		Water Ingestion (b) 0 cover	Indoor Radon Inhalation (c) 1' cover
Pb 210		0.4(9)	1.0(6)	<<1(6)	Residental	C= 10/2.5= 4(I)	C=10/1.3=7.6(I)
Bi 210				.02(15)			
Po 210		0.14(9)	.15(6)				
Subchain dose	<<1	.02(3)	1.8(3)				
		.03(10)	0.3(4)	<<1(4)	Non-Resid	C=10/.5=20(I)	NP(6)
		0.5(9) .5	1.2(6) 2.0	<<1(6)			NP(I)
			2.3(10)	.02(15)			; determined by allowed Ra 226/Pb210 level
			0.8(11)				
			25.3(15)				
			1.8(16)				
			1.5(17)				
Pb 206 (stable)	----	---- - - -	-----	----		----	
Total dose	8.0(1)	0.4(3)	2.3(3)	.1(4)			
	8.0(4)	0.6(9)	0.3(4)	.1(6)			
	9.8(8)	0.6(10)	2.0(6)	.27(15)			
	10.9(9)		3.3(10)				
	11.0(12)		14.1(11)				
	19.3(14)		2.4(15)				
	15.4(15)						

fective dose equivalent in mrem per pCi/gm for 1 year of exposure
mmitted effective dose equivalent in mrem per pCi/gm for 1 year of exposure
i/l of radon per pCi/gm of radium 226 in soil

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TABLE 2: DOSE CONVERSION FACTORS; DOSE PER 1 PCI/GM OF SUBCHAIN PARENT NUCLIDE IN SOIL

Thorium 232, Radium 228, Thorium 228 Subchains (daughters in equilibrium)

Radioactive Isotope	External Gamma (a)	Direct Soil Ingestion (b)	Crop Ingestion (b)	Resuspension in Air-Inhalation (b)	Water Ingestion (b)	Indoor Thoron (c)
					O'cover	1'cover
Th 232(Y)		(.2) .002(3) .004(10) .2(9)	(5) .01(4) .55(6) .005(10) .06(15)	(.6) .08(4) .48(6) Res .07(10) 1.20(15) Non Res	C=10/1.3=8(I) C=10/.8=12(I)	C=10/.33=30(I) NP(I)
228 D Ra 228		.1(9)	.11(4) .58(6)		0.7(13)	
Ac 228	4.0(1) 3.2(4) 3.1(6) 6.0(9) 6.0(12)					
Subchain dose	(.7) 4.0(1) 3.2(4) 3.1(6) 6.0(9) 6.0(12) 10.2(14) 8.2(15)	.1(9)	(.4) .11(4) .58(6) .09(15)	<<1(4)	0.7(13) 0 cover Res. C=10/1.2=8(I) C=6/7=.9(G) C=4/.7=6(GW)	1'cover C=10/1.0=10(I) C=9(G) C=6(GW)
Th228(Y)		.03(9)	.04(4) .078(6)	.08(4) .14(6) .23(15)	C=10/.85=12(I) C=.9(G) Non Res C=4/.7×2=11(GW)	C=10/.7×2=28(I) C=9(G) C=11(GW)
Ra 224		.03(9)				
Rn 220(thoron)						
228 Po 216						
Pb 212	.72(4) .78(9) .70(12)					
Bi 212	.8(1) .6(4) 1.2(9) 1.2(12)					
Po 212(64%)						

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E 2: DOSE CONVERSION FACTORS; DOSE PER 1 PCI/GM OF SUBCHAIN PARENT NUCLIDE IN SOIL (CONTINUED PAGE 2)

Thorium 232, Radium 228, Thorium 228 Subchains (daughters in equilibrium)

Radioactive Isotope	External Gamma (a)	Direct Soil Ingestion (b)	Crop Ingestion (b)	Resuspension in Air-Inhalation (b)	Water Ingestion (b)	Indoor Thoron (c)
Tl 208(36%)	6.0(1) 4.8(4) 7.6(9) 8.3(12)					
Subchain dose 9.3	6.8(1) 6.1(4) 9.6(9) 10.2(12) 17.0(14) 5.9(15)	.06(9) .06	.12 .04(4) .078(6) .20(15)	.08(4) .14(6) .13 .23(15)		
Pb 208(stable)						
Total dose:	10.8(1) 9.3(4) 15.1(8) 15.6(9) 16.2(12) 27.2(14) 14.1(15)	.002(2) .004(10) .36(9)	.16(4) 1.21(6) .35(15)	.16(4) .62(6) 1.43(15)		

	0 cover	1' cover
Residential	C = 10/.33 = 30(I)	C = 10/.08 = 125(I)
Non-residential	C = 10/.21 = 50(I)	C = No path
	C = .6(G)	C = 6(G)

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ffective dose equivalent in mrem per pCi/gm from 1 year of exposure
ommitted effective dose equivalent in mrem per pCi/gm from 1 year of exposure
Ci/l per pCi/gm

INITIAL ASSUMPTIONS AND RESULTANT CONCENTRATION EQUATIONS

- General Formula: C = allowed dose increment/DCF

- For "allowed" yearly gamma increment of 6 mrem:

$$C = 6/DCF(G) \qquad (2)$$

- For "allowed" incremental radon level of 3 pCi/l:

$$C = 3/DCF(RN) \qquad (3)$$

- For "allowed" ingestion (I) intake of 10 mrem per year:

  C = 10/DCF(I) : for subchains with short <u>effective</u> half-lives (4)

  C = 20/DCF(I) : for subchains with long <u>effective</u> half-lives (5)

- Assuming for present there is no significant thoron pathway

- Total Residual Concentration Level = $C + C_{BG}$

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RELATION BETWEEN ALLOWED BACKGROUND RATES, DOSE CONVERSION FACTORS, AND RESULTANT ALLOWED RESIDUAL SOIL CONCENTRATIONS

- General Formula: C = allowed dose increment/DCF

- For "Intake" category, background doses presented as yearly rates in NCRP 93, 94.

- Committed Effective Dose Equivalent (CEDE) more appropriate measure for pathway dose conversion factors: DCFs. See Attachment; Lifetime Risk Equations, esp. (15) (16) for effect of repeated intakes over 50 years.

- Compare the two by equating lifetime risk increments.

- For intakes with short effective half-lives:

  - allowed yearly background increment x 50 years x 5 x 10^{-7} health effects per mrem

    = DCF (CEDE) x C (allowed incremental radionuclide concentration) x 50 x 5 x 10^{-7}

  - therefore C = allowed yearly dose increment/DCF

- For intakes with long effective half-lives:

  - allowed yearly dose x 50 years x 5 x 10^{-7}

    = DCF (CEDE) x C x 25 x 5 x 10^{-7}

  - therefore C = 2 x allowed yearly dose increment/DCF

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(9)

Dose per 1 pCi/g in Soil
U-238, U-234, and U-235 Subchains

Isotope	External Gamma Radiation (a)	Child Soil Ingestion (b)	Crop Ingestion (b)	Resuspension in Air-Inhalation (b)	Water Ingestion (b)
U-238	.00003 (1) .0054 (6) .00015 (9) .00011 (12)	.02 (9) .02 (14)	.04 (4) .003 (6)	.07 (4) .05 (6) .05 (14)	.1 (14)
Th-234	.005 (1) .06 (4) .03 (9) .024 (12)	.001 (9)	.003 (6)		
Pa-234	7.6 (1) 6.2 (6) 11.0 (9) 12.0 (12)	.0002 (9)			
Pa-234m	.05 (1) .05 (4) .09 (9) .09 (12)				
Subchain Dose	7.7 (1) 6.2 (6) 9.8 (8) 11.0 (9) 11.4 (12) .04 (15)	.02 (9) .02 (14) .02 (15)	.04 (4) .006 (6) .004 (10) .007 (11) .04 (15) .06 (16)	.07 (4) .05 (6) .05 (14) .09 (15)	.1 (14)
U-234	.0004 (15)	.02 (9) .02 (14) .02 (15)	.04 (4) .003 (6) .005 (10) .008 (11) .04 (15) .06 (16)	.08 (4) .06 (6) .052 (14) .10 (15)	.1 (14)
Subchain Dose	.002 (15)	.02 (9) .02 (14) .02 (15)	.04 (4) .003 (6) .005 (10) .008 (11) .04 (15) .06 (16)	.08 (4) .06 (6) .052 (14) .10 (15)	.1 (14)

5

U238+D

10

.03

.07

	0' cover	1' cover
Residential	C ~ 10/.2 = 50(I) C = .6(G) C = 4/.1 = 40(GW)	C ~ 100(I) C = 6(G) C = 40(GW)
Non-Residential	C = 10/.14 = 71(I) C = .6(G) G = 80(GW)	C = 10/.1 x 2 = 200(I C = 6(G) C = 80(GW)

	0	1'
Resid	C = 10/.2 = 50(I) C = 4/.1 = 40(GW)	C = 10/.1 = 100 C = 40(GW)
Non Resident	C = 10/.14 = 71(I)	C = 10/.05 = 200

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U-238, U-234, and U-235 Subchains

Isotope	External Gamma Radiation (a)	Child Soil Ingestion (b)	Crop Ingestion (b)	Resuspension in Air-Inhalation (b)	Water Ingestion (b)
U-235	.32 (1) 1.1 (4) .23 (6) .8 (9) (12) 2.2 (14)	.02 (9) .02 (14)	.035 (4) .003 (6)	.075 (4) .053 (6) .050 (14)	.1 (14)
Th-231	.003 (1) .456 (4) .01 (6) .04 (9)	.0001 (9)			
Subchain Dose	(1.5) .32 (1) 1.6 (4) .3 (6) (12) 2.2 (14) .9 (15)	.02 (9) .02 (14) .02 (15)	.04 .035 (4) .003 (6) .04 (15) .06 (16)	.06 .075 (4) .053 (6) .05 (14) .09 (15)	.1 (14)

J-235 (D

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	0' cover	1' cover
Residential	C = 10/.2 = 50 (I) C = 6/1.5 = 4 (G) C = 4/.1 = 40 (GW)	C = 10/.13 = 77 (I) C = 40 (G) C = 40 (GW)
Non-Residential	C = 10/.05+.08 = 77 (I) C = 4 (G) C = 4/.05 = 80 (GW)	C = 10/.05 = 200 (I) C = 40 (G) C = 80 (GW)

Dose per 1 pCi/g in Soil
U-238, U-234, and U-235 Subchains

Isotope	External Gamma Radiation (a)	Child Soil Ingestion (b)	Crop Ingestion (b)	Resuspension in Air-Inhalation (b)	Water Ingestion (b)	
Pa-231	.034 (1)	.77 (9)	.28 (4)	.04 (4)		
Long	.7 (4)	.80 (14)	4.8 (6)	.37 (6)		
	.1 (6)	.80 (15)	1.5 (15)	.56 (14)		
	.2 (9)			1.0 (15)		
	.41 (14)					
	.07 (15)					
Subchain Dose	.04 (1)	.77 (9)	.28 (4)	.04 (4)	Ocover	1' cover
C_g large	.7 (4)	(.8) .8 (14)	(2.2) 4.8 (6)	(.5) .37 (6)	C=20/3.5=9(I)	C=20/1.5=13(I)
	.1 (6)	.8 (15)	1.5 (15)	.56 (14) Rea		
	(.2) .2 (9) (12)			1.0 (15)	C=6/.2=30(G)	C=300(G)
	.41 (14)					
	.07 (15)					
Ac-227		1.03 (9)	.16 (4)	.17 (4) Non R	C=20/1.3=15(I)	NP (I)
		1.02 (14)	.90 (6)	.57 (6)	C=30(G)	C=300(G)
			2.1 (15)	2.7 (14)		
				5.0 (15)		
Ra-223	.3 (1)	.05 (9)		.007 (4)		
	.9 (4)					
	.6 (9)					
Rn-219	.2 (1)					
	.3 (4)					
	.3 (9)					
AC227(D)						
Po-215	.0006 (1)					
	.001 (9)					
	.001 (12)					
Pb-211	.21 (1)					
	.20 (4)					
	.31 (9)					
	.31 (12)					
Bi-211	.17 (1)					
	.20 (4)					
	.30 (9)					
	.26 (12)					

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Dose per 1 pCi/g in Soil

U-238, U-234, and U-235 Subchains

Isotope	External Gamma Radiation (a)		Child Soil Ingestion (b)		Crop Ingestion (b)		Resuspension in Air-Inhalation (b)		Water Ingestion (b)
Tl-207	.01	(1)							
	.02	(9)							
	.02	(12)							
Pb-207 (Stable)									
Subchain Dose	.9	(1)	1.6	(9)	.16	(4)	.2	(4)	
	1.6	(4)	1.1	(15)	.90	(6)	.6	(6)	
	1.7	(9)			2.1	(15)	2.7	(14)	
(1.6)	.6	(12)	(1.6)		(1.0)		5.0	(15)	
	4.1	(14)					2.5		
	.84	(15)							

	0 cover	1' cover
Residential	C = 10/5.2 = 2(I)	C = 10/.66 = 20(I)
	C = 6/1.6 = 4(6)	C = 6/.16 = 40(6)
Non-Residential	C = 10/4.1 = 2.4(I)	NP(I)
	C = 4(6)	C = 40(6)

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(1) EPA Heast Tables, March, 1993 5×10^{-7} cancers/mrem; 50 year lifetime [risk x 4×10^{4} = mrem/year]

(2) EPA Heast Tables, March, estimate 365 pCi ingested using .2 gm a day for 5 years [.18 to 1.8 gms/day; CDC, Montclair Health Risk Assessment; EPA (OSWER); .2 gms/day]

(3) Interpolated from CDC Health Risk Assessment for Montclair

(4) NRC Branch Technical Position, adjusted to full occupancy for gamma exposure, and 56 kg/yr for vegetative intake

(5) 1 pCi/gm ≈ 1 pCi/l from EPA draft report: RAETRAN MODEL. Also assumes 5×10^{-3} cancers/ 1 pci/l of Rn-222 (central estimate: BIER IV report)

(6) Oak Ridge Draft Report PNL 72-12.

(7) Mrem/year = lifetime risk/50 years/5×10^{-7} health effects per mrem.

(8) NCRP Report #94, page 69, using body shielding factor of 0.7

(9) PNL Final Report/NUREG CR-5512; Table E.2, for gamma exposure, adjusted by 15% to depict 1 meter depth of material; assumes .2 gms per day for soil ingestion.

(10) Roy F. Weston Analyses for Montclair, Glen Ridge, West Orange Risk Assessment; based on elemental transfer factors from Brodsky, Allen; Handbook of Radiation Measurement and Protection, Volume 2, adjusted to 56 kgm/year vegetative intake for comparison with CDC numbers (#3).

(11) Roy F. Weston Analyses for Montclair, Glen Ridge, West Orange Risk Assessment; based on elemental transfer factors from EPA Document 520/1-84-002-1 "Radionuclides, Background Information Document for Final Rules;" Table A-6); adjusted to 56 kgm/yr vegetative intake

(12) EPA Federal Radiation Guidance Report #12

(13) Derived from Ra-226, 228 groundwater data: EPA NIRS survey and soil concentration data in paper by Myrick, Berven, and Haywood, Sept. 1982

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FOOTNOTES (continued)

(14) EPA Draft NORM Report

(15) RESRAD Implementation Manual, CCC 552, 7/1/90, adjusted to 56 kg/yr vegetative intake

(16) RESRAD Implementation Manual; 56 kg/yr intake; using EPA transfer factor

(17) NCRP 94; Pb 210 - Po 210 effective dose equivalent from natural sources 10.5 mrem/yr (derived from Table 9.2 of NCRP 94) ÷ 2 pCi/gm of Pb 210 in soil (from page 101); adjusted to 56 kgm/yr vegetative intake

(18) Ratio of average radon level in U.S. homes to average radium concentration in soils

(2T)

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SELECTED DCF's (mrem/yr per pCi/gm in soil)

Element(s)	Gamma No cover	Gamma 1 foot cover	Ingestion No cover	Ingestion 1 foot cover	Groundwater No cover	Groundwater 1 foot cover
Th230			.25	.07		
Ra226+D(1)	10	.1	2.7	1.7	.4	.4
Pb210+D			2.5	1.3		
Th232			1.3	.33		
Ra228+D	7	.7	1.2	1.0	.7	.7
Th228+D	9	.9	.3	.08		
U238+D	10	1	.2	.1	.1	.1
U234+D	---	---	.2	.1	.1	.1
U235+D	1.5	.15	.2	.13	.1	.1
Pa-231	.2	.02	3.5	1.5		
Ac-227	1.6	.16	5.1	.7		

Notes

- Resuspension and direct soil ingestion contributions nil for 1 foot cover
- Crop dose reduced by 33% for 1 foot cover as compared to no cover
- 20% radon emanation reduction assumed for 1 foot cover as compared to no cover

(1) Radon DCF = 1.25 (no cover) and 1.0 (1' cover); in pCi/l per pCi/gm

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Background Increments

- Preliminary Thoughts on Establishing Natural Background Levels

  * National data exists in NCRP Reports 93 and 94 for radon, terrestrial gamma and intake ("in the body") categories

  * Therefore can estimate natural background radiation ranges for:

    - Radon Exposure

    - External Gamma Exposure

    - Internal Dose

      • Combine natural background exposures for soil ingestion, crop ingestion, resuspension/inhalation and water ingestion pathways

  * Extent of range from mean levels (or the allowed incremental dose) needs to be established

    - One standard deviation is an accepted measure of statistical range without going to extremes

    - Use of one standard deviation results in about a 25% increment for terrestrial gamma radiation

  * Depending on the radionuclides and pathways involved, one of the three background values will be most restrictive and determine the allowable radionuclide soil concentration levels.

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TABLE 9.7—*Estimated total effective dose equivalent rate for a member of the population in the United States and Canada*[a] *from various sources of natural background radiation*

Source	Total effective dose equivalent rate (mrem/y)[b]					
	Lung	Gonads	Bone surfaces	Bone marrow	Other tissues[c]	Total
w_T	0.12	0.25	0.03	0.12	0.48	1.0
Cosmic	3	7	1	3	13	27
Cosmogenic	0.1	0.2	—	0.4	0.3	1
Terrestrial	3	7	1	3	14	28
Inhaled[d]	200	—	—	—	—	200
In the body	4	9	3	6	17	40
Rounded totals	210	23	5	12	44	300

[a] The effective dose equivalent rates for Canada are about 20% lower for the Terrestrial and Inhaled components.

[b] 1 mrem = 0.01 mSv.

[c] This is an approximation derived by assuming that the rest of the organs had the same dose equivalent rate as the gonads, adding 17 mrem/y.

[d] Derived from calculations of ICRP Publication 32 (ICRP, 1981c). (See NCRP, 1987b)

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9.2.3 *External Gamma Radiation*

The variability in this source is quite small, as described in Section 5. The distribution of exposures seems to be normal, with about 98 percent of the outdoor measurements in 4 countries being within 50 percent of the median value of 0.30 mGy/y (30 mrad/y). There are high natural areas, however, with a number of houses in the phosphate area of Florida showing 0.3 to 0.85 mGy/y (30 to 85 mrad/y) (Golden, 1986), and over 100 houses in Clinton, NJ at about 1.5 mGy/y (150 mrad/y) (Nicholls, 1986).

16 ~ 22 % of median

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9.2.5 *Radionuclides in the Body*

There are so few measurements on radionuclides other than ^{40}K in the body that no estimate of variability is made here. The dominant dose equivalent rate comes from ^{40}K and the total amount of potassium in the body is a direct function of lean body mass, with females receiving a dose equivalent rate about 25 percent less than males. As noted in earlier NCRP reports, measurements of ^{226}Ra and ^{210}Pb in autopsy bone specimens from areas with different concentrations in drinking water would be very helpful in improving our exposure data.

- NCRP Reports 93 and 94; 3 major "background" categories; radon, terrestrial gamma, "in the body"

1. radon

   - convert state measurement data to lognormal form and determine one standard deviation level

   - statewide geometric mean = 1.35 pCi/l; 1 σ = 2.94 pCi/l; sum = 4.29 pCi/l

   - allow a 3 pCi/l increment; brings total level to about 4 pCi/l which is comparable with "natural" radon program guidance

2. <u>terrestrial</u> gamma radiation

   - average for U.S.; 28 mrem year

   - variability; ~ 2.3 σ within ± 50 % of average

   - therefore allow a 1 σ or 22% increment, or about 6 mrem

3. "In the body" radionuclides

   - food, water, inhalation (except radon), resuspension, etc.

   - average for United States: about 40 mrem per year

   - allow 25% increment, or 10 mrem per year

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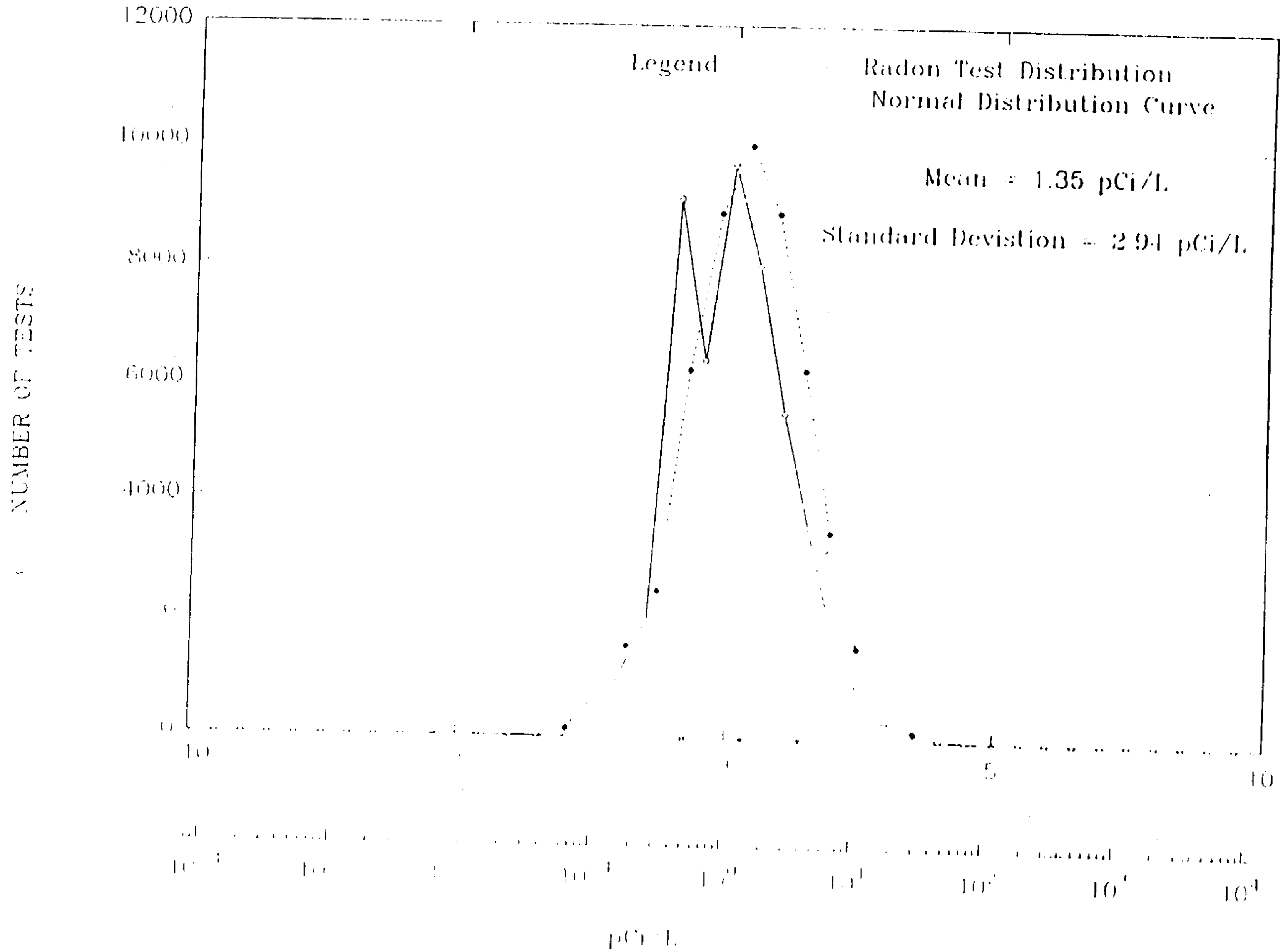
RADON TEST DISTRIBUTION - NJ



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ALLOWED INCREMENTAL SOIL CONCENTRATION LEVELS - PRELIMINARY

- Individual Subchains -

- pCi/gm -

Element/Subchain	no "clean" soil cover	1 foot of cover (1) (no gamma attenuation from buildings)	1 foot of cover (1) (25% gamma attenuation from buildings)
Uranium 238+D	.6(G)	6(G)	7.5(G)
U 234	50 (I) *40 (GW)	100(I) * 40(GW)	100 (I) 40(GW)
Th 230	40 (I)	140(I)	140(I)
Ra 226+D	* .6 (G) 3 (Rn) 6 (I)(2) 10 (GW)	6 (G) * 3 (Rn) 10 (I)(2) 10 (GW)	7.5(G) * 3 (Rn) 10 (I)(2) 10 (GW)
Pb 210+D	* 4 (I)	* 7.6 (I)	7.6(I)
U 235+D	4(G) 40(GW)	40(G) 40(GW)	50(G) 40(GW)
Pa 231	9(I)	13(I)	13(I)
Ac 227+D	4(G) 2(I)	40(G) 20(I)	50(G) 20(I)
Th 232	8 (I)	30 (I)	30(I)
Ra 228+D	* 0.9 (G) 8 (I) 6 (GW)	9 (G) 10 (I) * 6 (GW)	11 (G) 10 (I) * 6 (GW)
Th 228+D	* .6 (G) 30 (I)	* 6 (G) 125 (I)	* 7.5(G) 125 (I)

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PRELIMINARY RESIDENTIAL CLEAN-UP STANDARDS

- Using the DCF's and equations (2), (3), (4), and (5) determine allowed concentration level for each background category, i.e. radon, gamma, internal

- Determine the most restrictive pathway

- First consider undisrupted case, then disrupted case

OTHER CONSIDERATIONS

- Non-Independence of Subchains, i.e. ingrowth of daughters over time

  - Examples: Ra 226 (1600 y half-life) from Th 230(10^5y)

    Pb 210 (22y) from Ra 226 (1600y)

    Ra 228 (5.8 y) from Th 232(10^{10}y)

    Th 228 (1.9 y) from Ra 228(5.8y)

  - Ingrowth of Shorter Lived Daughters from Long-Lived Parent

    $A_D = A_D\, e^{-\lambda_D t} + A_p\,(1-e^{-\lambda_D t})$; where

    A_D = Activity of Daughter

    A_p = Activity of Parent

    $\lambda = .693/T_{½}$

  - Mid and Longer Term Activity at Remediated Site Driven by Residual Activity of Parent and Half-Life of Daughter

  - Therefore for moderate daughter half-lives, remediated activity level of parent should not exceed that of daughter

- Combinations of Subchains (within each of the 3 pathway categories)

  $$\frac{Ca}{C_A} + \frac{Cb}{C_B} + \ldots\ll 1$$

- Future disruption and erosion of cover

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G = Gamma pathway
I = Ingestion pathway
GW = Groundwater pathway
* = constraining pathway

(1) assumes 90% attenuation of gamma exposure per foot of soil cover, elimination of direct soil ingestion and resuspension components, and 33% reduction in crop ingested radionuclide dose conversion factor

(2) Used equation (12) in Attachment since effective half-life for bone (~ 44 years) is neither "long" nor "short" compared to 50 years.

Effect of Subchain Ingrowth

Combinations

- Longer lived parent subchain followed by shorter lived subchain(s)
- Apply combination formula
- Examples:
  - Ra 226 + D, Pb 210 + D
  - Th 232, Ra 228 + D, Th 228 + D
  - Pa 231, Ac 227 + D

For Ra 226 exceeding cleanup level:

Gamma:

$$\frac{C_{Ra\ 226}}{6} + \frac{C_{Pb\ 210}}{\infty} \leq 1 \quad : \quad C = \underline{6\ pCi/gm}$$

Ingestion:

$$\frac{C_{Ra\ 226}}{10} + \frac{C_{Pb\ 210}}{7.6} \leq 1 \quad : \quad C = \underline{4.3\ pCi/gm}*$$

For Thorium 232 exceeding cleanup level:

Gamma:

$$\frac{C_{Ra\ 228}}{9} + \frac{C_{Th\ 228}}{6} \leq 1 \quad : \quad C\ (equilibrium) = \underline{3.6*}\ pCi/gm$$

Ingestion:

$$\frac{C_{Th\ 232}}{30} + \frac{C_{Ra\ 228}}{10} + \frac{C_{Th\ 228}}{125} \leq 1 \quad : \quad C\ (equilibrium) = \approx 7\ pCi/gm$$

(1) 1 foot of cover; no gamma attenuation from buildings
* limiting pathway

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ALLOWED INCREMENTAL CONCENTRATION LEVELS (pCi/gm)

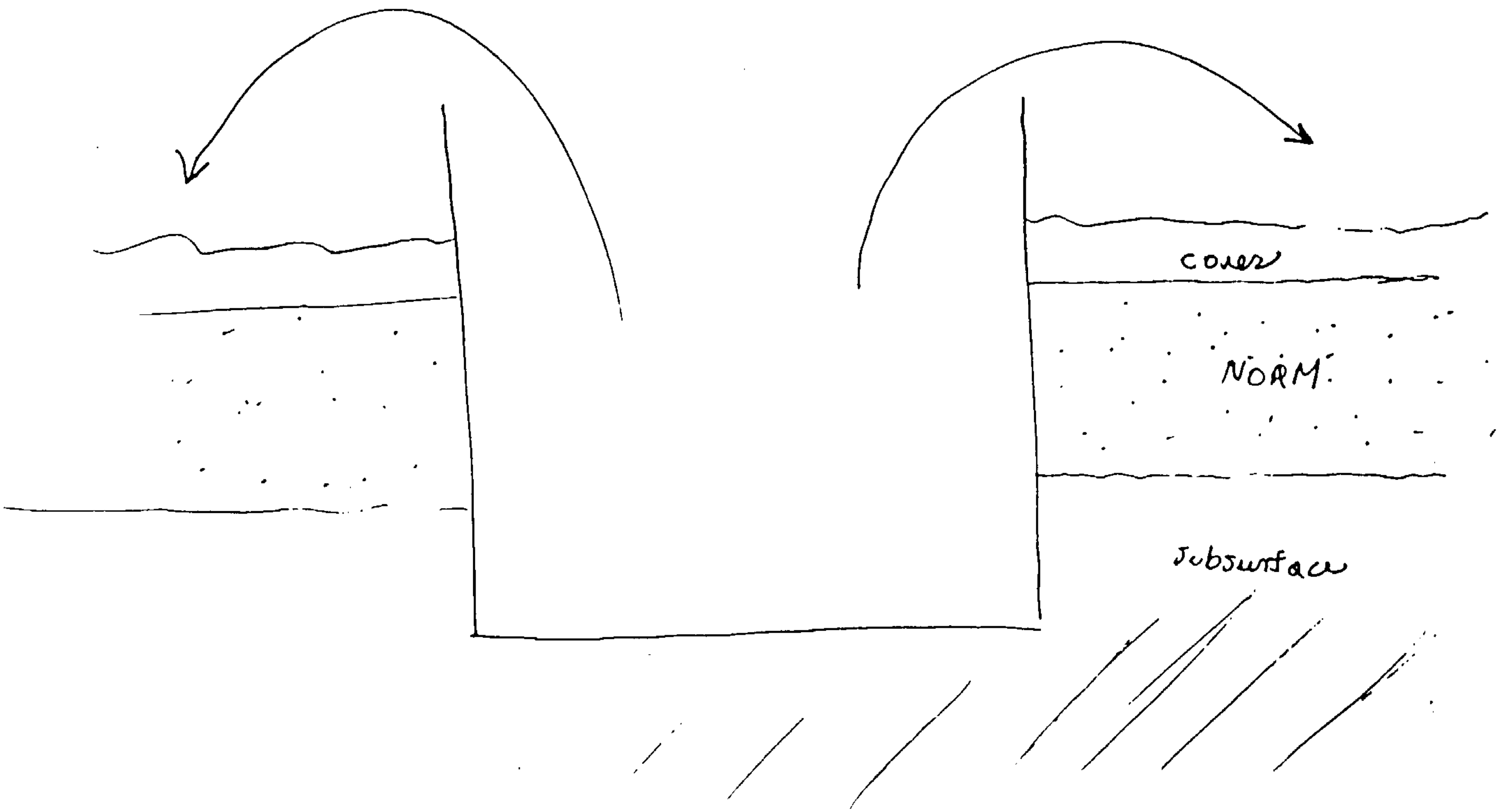
- Effect of Ingrowth Included -

Subchain	Concentration (1)	Concentration (2)	Concentration (3)
U 238 + D	6(G)	7.5(G)	9(G)
U 234	40(GW)	40 (GW)	40(GW)
Th 230			
Ra 226 + D	4.3(I),3(Rn),6(G)	3(Rn)4(I)	3(Rn)4(I)
Pb 210 + D	4.3(I)	4(I)	4(I)
U 235 + D	40(G),40(GW)	50(G),40(GW)	60(G),40(GW)
Pa 231	8(I)	8(I)	8(I)
Ac 227 + D	40(G), 8(I)	50(G), 8(I)	60(G), 8(I)
Th 232	3.6(G), 7(I)	4.5(G)	5.4(G)
Ra 228 + D	3.6(G), 7(I),6(GW)	4.5(G),6(GW)	5.4(G),6(GW)
Th 228 + D	3.6(G), 7(I)	4.5(G)	5.4(G)

1) 0% gamma building/occupancy reduction, 1 foot cover
2) 25% gamma building/occupancy reduction, 1 foot cover
3) 50% gamma building/occupancy reduction, 1 foot cover

- Excavation and disruption of cover
- Realistic for long lived radionuclides
- Assumes basement excavation to 8 foot depth
- Assumes mixing of cover, contaminated, and underlying zone, and placement on site surface (probably conservative)
- Example; 1 foot cover, 4 foot thickness of contamination, and rest clean underlayment results in
  - 50% mixing and concentration reduction of contaminated material
- Assumes an additional 30% gamma attenuation from house structure attenuation/occupancy

Disruptive Scenario



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Disruptive Scenario

- Material brought to surface
- Resultant doses estimated*

Element	Activity (pCi/gm)	DCF(G) (mrem/yr)	Dose(G) (mrem/yr)	DCF(I) (mrem/yr)	Dose(I) (mrem/yr)	DCF(GW) (mrem/yr)	Dose(GW) (mrem/yr)
Th230	3	---	---	.25	.4		
Ra226+D	3	10	11	2.7	4	.4	.6
Pb210+D	3	---	---	2.5	4		
Th232	5	---	---	1.3	3.3		
Ra228+D	5	7	12	1.2	3.0	.7	2
Th228+D	5	9	16	.3	0.8		
U238+D	8	10	28	.2	---	.1	.4
U234	40	--	--	.2	4	.1	2
U235+D	40	1.5	21	.2	---	.1	2
Pa-231	8	.2	1.6	3.5	14		
Ac-227	8	1.6	4.5	5.1	20		

* Assumes no cover; 50% concentration/attenuation from soil mixing due to basement excavation and an additional 30% gamma dose reduction from house shielding.

Radon doses expected to be less than those with cover intact due to Ra226 concentration reduction upon mixing.

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(4T)

Impact of Disruptive Scenario

- Ra226/Pb210 gamma dose ~ 11 mrem/yr ≈ 2 background standard deviations (acceptable)
- Ra226/Pb210 Ingestion dose ~ 8 mrem/year ~ 20% (OK)
- Ra228/Th228 gamma dose ~ 28 mrem/yr and is greater than 2σ
- Ra228/Th228 Ingestion dose ~ 7 mrem/year (OK)
- Policy? ; limit doses to 2 σ in disruptive scenarios?
- Reduce allowed Ra228/Th228 Concentrations by $\frac{16}{28}$ ≈ 60%
- Then, allowed concentration for Ra228, Th228 would be $\frac{2.0 \text{ pCi}}{\text{gm}}$,
- or reduce allowed thickness of contamination to 3'

  % mixing 3/8 = 37.5%

  Ra228/Th228 gamma dose = 21 mrem
- and reduce allowed Ra228/Th228 soil activity by 9/21 = 43%

  and C allowed = 5 x .57 ≈ 3 pCi/gm
- or?

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- U238: •gamma dose ~ 28 mrem > 2 σ

  •reduce allowed concentration by factor of about 12/28 = 43%

  •allowed concentration = 4 pCi/gm

- U235: gamma dose ~ 21 mrem > 2 σ

  reduce allowed concentration by factor of 12/21 = 57%

  allowed concentration = 23 pCi/gm

- Pa-231, Ac-227: Ingestion dose (total) ~ 34 mrem > 2 x 10 mrem allowance

  reduce allowed concentration by factor of 20/34 = 59%

  allowed concentration = 8 x .59 = 5 pCi/gm

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COMPARISON OF INITIAL RESULTS TO OTHER AGENCIES/ORGANIZATIONS

- INCREMENTAL ALLOWED CONCENTRATIONS -

RESIDENTIAL STANDARDS

Element(s)	DEPE[5]	Health Physics Society	EPA (Radiation and Superfund Programs)	NRC[2] Branch Technical Position
Ra226	3	5	5	4[3]
Pb210	3	5[1]	5	
Th232	3	5	5	4[4]
Ra228	3	5	5	
Th228	3	5[1]	5	4[4]
U238	4			4[6]
U234	40			4[6]
U235	23			
Pa-231	5			
Ac-227	5			

1) Assumed, based on ingrowth and HPS position on parent subchains
2) Under revision
3) Presented as 5 pCi/gm, including background
4) Presented as the sum of Th232 plus Th228 equal to 10 pCi/gm, including background
5) Assumes 1' of cover, maximum thickness of contaminated zone 3-4 feet
6) Presented as the sum of U238 + U234 equal to 10 pCi/gm, including background

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- Results in about 4 picocuries/gm range allowed concentrations
- Results compatable with EPA, NRC, HPS analyses
- Potential publically acceptable rationale
- Lifetime risks on order of 10^{-4} or less (within EPA "Superfund" Ranges)

	C	G*	I*
Ra226	4.0	1.0×10^{-4}	1.0×10^{-4}
Pb210	4.0	----	1.3×10^{-4}
Ra228	4.5	6×10^{-5}	1.0×10^{-4}
Th228	4.5	1.0×10^{-4}	10^{-5}

- Issues to pursue
  - Building Gamma attenuation factors
  - Pb210 uptake
  - cover erosion rates
  - radon emanation factors for processed ores
  - $ $ (funding)

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ENCLOSURE 2

RESIDENTIAL AND NON-RESIDENTIAL STANDARDS

- INCREMENTAL ALLOWED CONCENTRATIONS (pCi/gm) -

Element(s)	Residential	Non-Residential
Ra226	3	6
Pb210	3	6
Th232	3	6
Ra228	3	6
Th228	3	6
U238	4	7
U234	40	80
U235	23	48
Pa-231	5	7
Ac-227	5	7

IMPACT OF DISRUPTIVE SCENARIO

- Ra226 gamma dose ~ 10 mrem/yr (ok)
  - Allowed concentration is 6 pCi/gm

- Ra228/Th228 gamma dose ~ 29 mrem/year (too high)

  - reduce by factor of $\frac{12}{29}$ = .41%

  - allowed concentration = 11 x .41 = 4.5 ≈ <u>5 pCi/gm</u>

  or

  - reduce thickness of contamination to 3', and

  - allow concentration ≈ <u>6 pCi/gm</u>

- U238 gamma dose from 18 pCi/gm ~ 30 mrem/yr

  - reduce by $\frac{12}{30}$ ~ 40%

  - allowed concentration = 18 x .4 = <u>7 pCi/gm</u>

- U235 gamma dose from 80 pCi/gm ~ 20 mrem/yr

  - reduce concentration by factor of $\frac{12}{20}$ = <u>60%</u>

  - allowed concentration = 80 x .6 = 48 pCi/gm

- U234 Ingestion dose = 5.6 mrem/yr (OK)

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Pa231 & Ac227 Ingestion dose from 105 pCi/gm = 283 mrem/year

- reduce concentration by factor of $\frac{20}{283}$ = 7.06%

- allowed concentration = 105 x .0706 = 7.4 pCi/gm

- PA231 & Ac227 gamma dose from 105 pCi/gm = 31.5 mrem/year

- reduce allowed concentration by $\frac{12}{31.5}$ = 38%

- Ingestion dose controlling

- allowed concentration = 7.4 pCi/gm

Disruptive Scenario

- Excavation and disruption of cover for industrial buildings
- Assumes basement excavation to 8 foot depth
- Assumes mixing of cover, contaminated, and underlying zone, and placement on surface
- Example; 1 foot cover, 4 foot thickness of contamination, and rest clean underlayment results in ~ 50% mixing and concentration reduction of contaminated material
- Assumes an additional 66% gamma attenuation from building structure attenuation/occupancy
- Assumes a 100% reduced occupancy related exposure to radon gas as compared to residential scenarios

NON-RESIDENTIAL STANDARDS

Disruptive Scenario

- Material brought to surface
- Resultant doses estimated*

Element	Subsurface Activity (pCi/gm)	DCF(G) (mrem/yr)	Dose(G) (mrem/yr)	DCF(I) (mrem/yr)	Dose(I) (mrem/yr)	DCF(GW) (mrem/yr)	Dose (GW) (mrem/yr)
Th230	6	---	---	.15	.5		
Ra226+D	6	10	10	.5	1.5	.2	1.2
Pb210+D	6	---	---	.5	1.5		
Th232	11	---	---	.8	4.4		
Ra228+D	11	7	13	.9	5.0	.35	3.85
Th228+D	11	9	16	.2	1.1		
U238+D	18	10	30	.14	1.3	.05	.5
U234	80	--	--	.14	5.6	.05	2
U235+D	80	1.5	20	.13	5.2	.05	2
Pa-231	105	.2	3.5	1.3	68		
Ac-227	105	1.6	28	4.1	215		

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*Assumes no cover; 50% concentration/attenuation from soil mixing due to basement excavation and an additional 66% gamma dose reduction from house shielding/occupancy factors.

G = Gamma pathway
I = Ingestion pathway
GW = Groundwater pathway
* = constraining pathway
(1) assumes no vegetables grown on site
(2) assumes 90% attenuation of gamma exposure per foot of soil cover, and elimination of direct soil ingestion and resuspension components

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ALLOWED INCREMENTAL CONCENTRATION LEVELS (pCi/gm)

- Effect of Ingrowth Included -

Subchain	Concentration [1]	Concentration [2]	Concentration [3]	Concentration [4]
U 238 + D	6(G)	7.5(G)	9(G)	18(G)
U 234	80(GW)	80(GW)	80(GW)	80(GW)
Th 230				
Ra 226 + D	50(I),3(Rn),6(G)20(GW)	3(Rn)7.5(G)	3(Rn)9(G)	6(Rn),18(G)
Pb 210 + D	3	3	3	6(Ra226)
U 235 + D	40(G) 80(GW)	50(G) 80(GW)	60(G) 80(GW)	120(G) 80(GW)
Pa 231	35(G)	44(G)	52(G)	105(G)
Ac 227 + D	35(G)	44(G)	52(G)	105(G)
Th 232	3.6(G),28(I),11(GW)	4.5(G),11(GW)	5.4(G),11(GW)	11(G),11(GW)
Ra 228 + D	3.6(G), 28(I),11(GW)	4.5(G),11(GW)	5.4(G),11(GW)	11(G),11(GW)
Th 228 + D	3.6(G),28(I),11(GW)	4.5(G),11(GW)	5.4(G),11(GW)	11(G),11(GW)

[1] 0% gamma building/occupancy credit, 1 foot cover
[2] 25% gamma building/occupancy credit, 1 foot cover
[3] 50% gamma building/occupancy credit, 1 foot cover
[4] 200% gamma building/occupancy credit, 1 foot cover, and 100% radon exposure credit for reduced occupancy in industrial building (~35%) as compared to a residence (~70%).

[Not]e: Shielding/occupancy factor = 1/(1+credit)
% reduction = 1 - 1/1+c

NON-RESIDENTIAL STANDARDS

SELECTED DCF's (mrem/yr per pCi/gm in soil)

Element(s)	Gamma No cover	Gamma 1 foot cover	Ingestion No cover	Ingestion 1 foot cover	Groundwater No cover	Groundwater 1 foot cover
Th230			.15			
Ra226+D[1]	10	1	.5	.2	.2	.2
Pb210+D			.5			
Th232			.8			
Ra228+D	7	.7	.9	.35	.35	.35
Th228+D	9	.9	.2			
U238+D	10	1	.14	.05	.05	.05
U234			.14	.05	.05	.05
U235+D	1.5	.15	.13	.05	.05	.05
Pa-231	.2	.02	1.3	---	---	---
Ac-227	1.6	.16	4.1	---	---	---

Notes

- Resuspension and direct soil ingestion contributions nil for 1 foot cover
- Crop dose assumed to be zero with or without cover
- Groundwater DCF assumed to be one half of residential value (50% water consumption)

*(1) DCF for radon assumed as 1.25 for no cover, 1.0 for 1' cover; in pCi/l per pCi/gm Ra226

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NON RESIDENTIAL USE

ALLOWED INCREMENTAL SOIL CONCENTRATION LEVELS (pCi/gm) - PRELIMINARY

- Individual Subchains -

Element/Subchain	no "clean" soil cover(1)	1 foot of cover (2) (no gamma attenuation from buildings/occupancy)	1 foot of cover (2) 25% gamma attenuation credit from buildings/ occupancy)
Uranium 238+D	*.6(G)	*6(G)	*7.5(G)
U 234	*71(I) 80(GW)	*80(GW)	*80(GW)
Th 230	66 (I)	--	--
Ra 226+D	* .6 (G) 3 (Rn) 20 (GW) 34 (I)	6 (G) * 3 (Rn) 20(GW) 50 (I)	7.5(G) * 3 (Rn) 20 (GW) 50 (I)
Pb 210+D	* 20 (I)	--	--
U 235+D	* 4(G) 80(GW,I)	* 40(G) 80(GW)	* 50(G) 80(GW)
Pa 231	* 15(I) 30(G)	300(G)	380(G)
Ac 227+D	4(G) 2.4(I)	40(G) --	50(G) --
Th 232	12(I)	--	--
Ra 228+D	* 0.9 (G) 12 (I) 11 (GW)	* 9 (G) 28 (I) 11 (GW)	* 11 (G) 28 (I) * 11 (GW)
Th 228+D	* .6 (G) 50 (I)	* 6 (G) --	* 7.5(G) --

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NON-RESIDENTIAL CLEANUP STANDARDS FOR DIFFUSE NATURALLY OCCURRING RADIOACTIVE MATERIALS (NORM).

Bob Stern, Chief
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NON-RESIDENTIAL USE STANDARDS

- Assumes adequate controls to prevent residential use
- Assumes radon background increment of 3 pCi/l must still be met in non-residential buildings but occupancy is 50% that of a residence
- With 1 foot cover assumes no direct soil ingestion, crop intake or air resuspension
- Therefore with cover, the only ingestion pathway is to groundwater, and for groundwater pathway, 4 mrem SDWA requirements supersede the 10 mrem ingestion background
- Without cover, also assumes groundwater pathway alone must be less than 4 mrem
- Without cover, assumes direct soil ingestion, resuspension, and groundwater contributions (no vegetative intake) must be less than 10 mrem background increment
- Assumes gamma exposure halved relative to residential setting (35% factors vs. 70%)
- Assumes disruptive scenario, involved in construction of industrial buildings