Health Assessment for
Montclair, Glen Ridge and West Orange, N.J.

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Center for Environmental Health
Centers for Disease Control

Background

In the past, health assessments by the Centers for Disease Control[1] for residents of Montclair, West Orange and Glen Ridge, New Jersey have assumed that future exposure would be limited to a relatively short period (about two years) rather than extending over a long period of time. Over a short time, residents may alter their behavior in order to lower their risk, but over many years a number of factors can change that make reliance on changes in behavior an unreliable way of decreasing exposures. Some of these factors are:

1. necessary repairs or alterations in the house or repairs to driveways, sidewalks, etc.

2. changes in living patterns
   addition of children
   change in age of children
   retirement - increased leisure time
   addition of pets
   change in economic status
   sale or lease of the home

3. changes in perception of risk over time.

The following assessment was designed to evaluate the long-term risks to residents of Montclair and Glen Ridge and to evaluate new environmental and exposure data that have become available. This assessment was based on data provided by the U.S. EPA region II, Emergency Response and Remedial Division and Region II REM contractor, Camp Dresser and McKee Inc. This assessment considers exposures due to soil ingestion, vegetable ingestion, soil disturbance, whole-body external gamma radiation, radon, and water contamination. The risks given in this assessment are excess risks and do not include the background risk for cancer.

Soil Ingestion

The direct ingestion of soil can be an important environmental pathway of radiation exposure for children in Montclair, West Orange and Glen Ridge. Children may ingest soil including sub-surface soil during play if their activities involve digging or if the ground has been cultivated. In Glen Ridge, core samples analyzed at depths from 0.5 to 1.0 feet ranged from 45 to 2,200 pci/gm for $radium^{226}$ and in Montclair up to 2,000 pci/gm. (Data are not available for West Orange.) While surface samples were not taken, a limited number of organic soil samples at 0.5 ft. had an average concentration of 100 pci/gm indicating that elevated concentrations do exist at the surface so that children may ingest contaminated soil. Other radioactive isotopes are also present above background levels and will be ingested along with radium including isotopes of uranium, thorium and lead. The equilibrium ratios for each isotope relative to radium ^{226} are given in Table A of the appendix for the most important isotopes.

In calculations of the risk to children, we assumed that children ages 1 to 6 ingest from 0.181 grams to 1.8 grams of soil per day.[3] The activity ingested for each isotope is given in the appendix in Table B. Actual exposures to children will vary widely. Children playing on highly contaminated areas could easily ingest the average surface concentration daily and peak concentrations regularly. Children playing on less contaminated areas may ingest background levels primarily mixed with occassional extreme exposures. However, for all children the potential for exposure to elevated levels is substantial. We have assumed that children are exposed to 100 pci/gm or 40 pci/gm daily and to concentrations of 2,000 pci/gm for 7 days each year. For exposures at average soil concentrations of 100 pci/gm or 40 pci/gm plus occasional exposures to peak concentrations of 2,000 pci/gm, the total committed dose to bone is 62 and 38 rem respectively (this includes 19 rem from the 7 day exposure to 2000 pci/gm). The 50 year committed dose to bone from selected isotopes is given in Table 1[2]. Estimates for the lifetime risk of dying from bone cancer range from 5 $\times 10^{-6}$ per rem [4] to 27 $\times 10^{-6}$ per rem [5] to bone. The excess risk of dying from bone cancer for individuals who ingested dirt as children for 5 years at 100 pci/gm or 40 pci/gm (plus 7 day/yr exposures to 2,000 pci/gm) of each isotope in Table 1 is 3 - 16 $\times 10^{-4}$ and 2 - 10 $\times 10^{-4}$ respectively.

Table 1
Fifty year committed dose in REM to bone from direct soil ingestion by children over ages 1 - 6

Isotope	soil concentration (pci/gm) 100	40
Ra^{266}+D	9.0 - 90	3.9 - 39
Th^{232}+D	0.054 - 0.54	0.023 - 0.23
Th^{230}+D	0.060 - 0.60	0.026 - 0.26
Pb^{210}+D	0.45 - 4.5	0.20 - 2.0
total	9.6 - 96	4.1 - 41
median	43 rem	19 rem

3.0 X 10^5 mrem/microcurie ingested (ref. 2)

Prevention of soil ingestion on any long term basis would imply constant supervision of children or not allowing them to play outside. Both of these alternatives are unrealistic. Restriction of areas of high contamination in the form of behavior changes or physical barriers does not seem feasible in most instances because without physical barriers children will not avoid "forbidden" areas when unsupervised and because some "hot" areas surround significant portions of residences.

Ingestion of Radium - 226 through vegetables

Gardens located in areas of contamination will lead to the ingestion of $radium^{226}$ through vegetable consumption for both adults and children. Table 2 gives the lifetime risk of death from bone cancer from eating vegetables grown at various soil concentrations from $radium^{226}$ only. These calculations assume that residents obtain 50% of their vegetables from their own garden or 56 kgm each year per person in the average household.[2]

Table 2
Lifetime risk of death from bone cancer from ingestion of vegetables grown in $radium^{226}$ contaminated soil over 60 years+

radium content of soil(pci/gm)	50 yr. committed dose per year of ingestion (Rem)	lifetime risk 60 year exposure	lifetime risk one year exposure
2,000	25.6	8 - 42 X 10^{-3}	1 - 7 X 10^{-4}
500	6.4	2 - 10 X 10^{-3}	3 - 17 X 10^{-5}
100	1.3	4 - 21 X 10^{-4}	6 - 35 X 10^{-6}
40	0.5	1 - 7 X 10^{-4}	2 - 11 X 10^{-6}

+ 3.0 X 10^5 mrem/microcurie ingested (ref. 2)
1.4 X 10^{-3} (pci/kgm plant)/(pci/kgm soil)

The risks from bone cancer and doses to bone associated from the ingestion of Pb^{210} in vegetables are given in Table 3. It is expected that Ra^{226} and Pb^{210} will provide the most significant exposures through this route.

Table 3
Lifetime risk of death from bone cancer from ingesting vegtables grown in soil contaminated with Pb^{210}

lead -210 content of soil(pci/gm)	50 yr. committed dose per year of ingestion (Rem)	lifetime risk 60 year exposure	lifetime risk for one year exposure
2,000	114	3 - 18 X 10^{-2}	5 - 30 X 10^{-4}
500	28	8 - 43 X 10^{-3}	1 - 7 X 10^{-4}
100	6	2 - 9 X 10^{-3}	3 - 15 X 10^{-5}
40	2	7 - 36 X 10^{-4}	1 - 6 x 10^{-5}

6.8 X 10^{-2} (uci/kg plant)/(uci/kg soil)
1.5 X 10^4 mrem/uci ingested

Table 4 gives the total lifetime risk of dying from bone cancer for vegetable ingestion routes. Each year residents live on contaminated porperty, their excess risk of dying from bone cancer may increase by 0.13 - 37 X 10^{-4} from vegetable consumption.

Table 4
Total Lifetime risk of dying from bone cancer from vegetable ingestion pathways

soil concentration (pci/gm)	lifetime risk 60 year exposure
2,000	4 - 22 X 10^{-2}
500	1 - 5 X 10^{-2}
100	2 - 11 X 10^{-3}
40	8 - 42 X 10^{-4}

Radium^{226} and Pb^{210} and their decay products give significant doses to organs other than bone when ingested. Ratio's between doses to other organs and to bone are given in Table C in the appendix. The organ doses from ingestion of vegetables at various soil concentrations of radium and lead are given in Table 5 for radium and lead. The risks from these exposures are difficult to predict because of the uncertainty in risk estimates for some organs. However, the dose to some organs is considerable even at moderately elevated levels.

Table 5
Committed dose in rem to organs from ingestion of Ra^{226} and Pb^{210} in vegetation per year

soil concentration (pci/gm)	Ra-226			Pb-210	
	whole body	GI tract	kidney	liver	kidney
2,000	19	26	14	32	91
500	5	7	3	8	22
100	0.9	1	0.7	2	5
40	0.4	0.5	0.3	0.6	2

Soil Disturbance

Both adults and children may come into direct contact with highly contaminated soil if the ground is disturbed by common activities such as cultivation for gardens, landscaping such as reseeding lawns or planting shrubs, flowers, trees, etc. and repairing or adding driveways, walkways, decks and porches. These are common activities and should be expected even when residents have been warned about "hot" spots. Near surface contamination may be brought to the surface during any digging activity, greatly raising the potential for exposure. To expect residents to permanently (or even over several years) refrain from all of the activities listed above is unrealistic. Direct contamination of hands and clothing with highly contaminated soil is quite possible during gardening, etc. and could lead to excess internal and external exposures as well as contamination inside homes.

Gamma Radiation

Residents are exposed to whole-body external gamma radiation from buried radium waste in their yards and under their homes. Twelve properties are known to have a combination of indoor and outdoor exposures that could lead to doses above 250 mrem per year. Calculations have been made only for houses with indoor radon problems so that more residents may have exposures above 250 mrem than given here. The estimates of exposure used in this assessment were made by EPA and are based on 75% percent occupancy at the average basement level and 25% at the average outdoor level. Outdoor gamma levels exceed 50 microR/hr on thirty-two properties. Exposure rates of 300 microR/hr are fairly common and levels as high as 400 to 500 microR/hr occur in limited areas. Residents may receive significant doses from these elevated gamma levels. Actual doses are difficult to calculate or predict because the size of the dose depends heavily on the living patterns of each resident. A summary of gamma exposure data is given in Table 6.

Table 6
Summary of Gamma Exposure Data

	Number of Houses			
	Glen Ridge	Montclair	West Orange	total
soil removal fully or partially completed	4	5	0	9
indoor gamma shielding complete	2	2	1	5
estimated average gamma exposure larger than 250 mrem per year	2	7	3	12
outside gamma levels above 50 microR/hr	9	18	5	32

The risk estimate used in this report, 2×10^{-4} deaths/rem, from the National Council on Radiation Protection[4] includes the deaths in future generations due to the genetic effects of radiation. The lifetime risks including genetic effects for various dose levels are provided in Table 7. The risk due to cancer in the current generation is 1/2 the total risk given in the table. Residents who receive 250 mrem/yr have an additional excess risk of dying from radiation induced cancer of 2.8×10^{-5} each year they live in their home. At 500 mrem/year the residents' risk rises by 5.5×10^{-5} each year.

Table 7
Lifetime risk of death from radiogenic cancer and genetic effects from external gamma exposure

annual whole-body gamma exposure	lifetime risk+ 70 year exposure	lifetime risk from one year exposure
200 mrem	3.0×10^{-3}	4.3×10^{-5}
500 mrem	7.5×10^{-3}	1.1×10^{-4}
1,000 mrem	1.5×10^{-2}	2.1×10^{-4}

+ref. 4

Radon

Houses that were designated as "A" or "B" homes were ventilated by EPA to reduce radon exposure to those residents quickly.[1] Homes designated as "C" homes were only recently ventilated so that the success of ventilation can not be evaluated yet in those residences. However, data are available to calculate an annual average radon concentration for A and B homes. The average results for 4 consecutive quarters are given in Table 8. The data in Table 8 indicate that eight homes have average radon levels on the first floor above 0.02 wl and 10 homes have levels above 0.02 in the basement. Whether a basement should be considered a living area depends on how the particular homeowner uses the basement now or may use it in the future. Even at radon daughter concentrations of 0.02 wl the excess lifetime risk is $1 - 4 \times 10^{-4}$ for each year of exposure. At a concentration of 0.05 wl the risk per year of exposure rises to $0.4 - 2 \times 10^{-3}$. One side effect of remedial actions dependent on ventilation in these homes is that in about 9 homes the radon levels on the first floor are now higher than levels in the basement. Ventilated houses will require periodic monitoring to ensure that ventilation systems are still functioning. In addition, the ventilation systems themselves will require continual maintenance.

Table 8

Lifetime risk of death from lung cancer based on radon levels averaged over 4 quarters after ventilation in homes originally designated as A or B

working level	number of houses in each range: living area	number of houses in each range: basement	lifetime risk per 1000* 70 yr. exposure	lifetime risk per 1000 one year exposure
0.01			7 - 30	0.10 - 0.43
	4	3		
0.02			13 - 50	0.19 - 0.71
	5	7		
0.05			30 - 120	0.43 - 1.7
	3	0		
0.10			60 - 210	0.86 - 3.0

*EPA risk estimates for lifetime radon exposure

Water Contamination

While water samples have been analyzed for Ra^{226}, adequate data are not available on background water concentrations of radium in New Jersey to determine if ground water systems have been contaminated. Appropriate background values should be obtained for comparison with water samples already taken.

Summary

It is important to note that each resident may acrue an excess risk through each route of exposure described, including ingestion of radium and other radioisotopes, contamination of clothes and homes from contact with the soil, whole body external radiation and indoor radon. Since the half-life of $radium^{226}$ is about 1600 years, the concentrations of radium in the soil and the associated risks will not decrease over the lifetime of the residents nor over the useful life of the homes. Under current conditions the radium contaminated soil cannot be contained in a way that will prevent significant exposures to residents. Children playing in contaminated areas of Montclair, Glen Ridge or West Orange may ingest soil contaminated with radium, lead, uranium and thorium. The excess risk of dying from bone cancer from ingesting soil ranges from 0.2 - 1.6 X 10^{-3}. Ingestion can also occur through food chains. Both adults and children may consume vegetables grown in contaminated areas with an associated lifetime risk of 2 - 11 X 10^{-3} at soil concentrations of 100 pci/gm for radium and lead. In addition organs other than bone will also receive significant doses from the ingestion pathway including the whole-body, the gastrointestinal tract, kidneys, and liver. The exposure from direct soil contact during gardening or other activities is more difficult to estimate. However, highly contaminated soil exists very close to the soil surface where it can be easily disturbed during any type of digging increasing the probability and severity of exposure through ingestion or external radiation. In addition, residents could easily carry contaminated soil into their homes on shoes and clothing.

Residents are exposed directly by gamma radiation from contamination surrounding or underneath their homes. Some estimates of gamma doses have been made but actual doses will depend upon the particular resident and how much time they spend indoors or in particular areas of their property. Calculations indicate that residents in 12 homes currently may receive over 250 mrem per year. The excess lifetime risk of dying from cancer for these residents from external gamma exposure is 2.0×10^{-3}. (If the genetic component of the risk is included the excess risk rises to 3.8×10^{-3}.)

While ventilation equipment was installed in many homes to lower indoor radon concentrations, 8 houses originally classified as tier A or B have average indoor levels above 0.02 wl with 3 above 0.05 wl. For lifetime exposure at 0.02 wl , the risk of dying from lung cancer ranges from $1 - 5 \times 10^{-2}$. Because of the large risk associated with radon, even at the recommended remedial action level, indoor radon concentrations should be lowered as much as possible below 0.02 wl.

While indoor radon poses the largest single risk to most residents, other exposure pathways cannot be ignored and must be addressed in plans to remediate Montclair, Glen Ridge and West Orange. Each year residents continue to live on contaminated areas their excess risk of dying due to radiation induced cancer increases significantly. This ongoing exposure adds to the risk these residents have already accrued while living in these homes. The annual excess risk to a significant number of residents clearly exceeds the 10^{-6} to 10^{-5} range. While it may not always be possible to lower the risks from environmental contaminants to below 10^{-5} or 10^{-6} (such as with indoor radon), the levels of risk to these residents from radioactively contaminated soil warrant expedient action to substantially lower the risk to current and future residents. Actions to lower exposure that depend upon permanent changes in behavior or on mechanical and barrier type systems that may be easily destroyed by residents during common home repairs or additions are not desirable means of lowering exposure and may be ineffective over long periods of time.

Appendix

Table A

ratios of radionuclides in core samples (some isotopes were not measured and values are estimated by CDM)

isotope	ratio
U^{238}	1
U^{234}	1
Th^{232}	10
Th^{230}	10
Ra^{226}	10
Pb^{210}	10

Table B

Ingestion in microcuries for Ra^{226}, Pb^{210}, Th^{232} and Th^{230} over five years by children

soil concentration pci/gm	5 year ingestion
100	0.03 - 0.33
40	0.013 - 0.13
2,000+	0.013 - 0.13

+ 7 day/yr exposure

Table C
Ratios of dose to organs and whole body to bone doses (dose X/dose bone)

organ	Ra^{226}+D	Pb^{210}+D
whole body	0.73	0.036
bone	1.0	1.0
kidney	0.53	0.80
GI-LLI	1.1	-
liver	-	0.29

(Brodsky)

References

[1] Centers for Disease Control. Public Health Advisory for Montclair and Glen Ridge, New Jersey, December 6, 1983.

[2] Brodsky Allen, ed. Handbook of Radiation Measurement and Protection, vol 2. Biological and Mathemantical Information, CRC Press, Boca Raton, 1982.

[3] Binder Sue, David Sokal, David Maughan. Estimating Soil Ingestion: The use of tracer elements in estimating the amount of soil ingested by young children. In Press: Archives of Environmental Health.

[4] National Council on Radiation Protection and Measurements. Exposures from the Uranium Series with Emphasis on Radon and its Daughters, report no. 77, Bethesda. 1984.

[5] Committee on the Biological Effects of Ionizing Radiations. The effects on Populations of Exposure to Low Levels of Ionizing Radiation. National Academy Press, Washington DC, 1980.