DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

Agency for Toxic Substances
and Disease Registry
Atlanta GA 30333

Health Consultation

Industrial Excess Landfill (5PW2)
Uniontown, Ohio

Federal Programs Branch
Remedial Programs Branch
Division of Health Assessment and Consultation

April 5, 1994

BACKGROUND AND STATEMENT OF ISSUES

The Industrial Excess Landfill (IEL) in Uniontown, Ohio is on the National Priorities List (NPL) of the U.S. Environmental Protection Agency (USEPA). Concerned Citizens of Lake Township (CCLT), composed of members of the community surrounding the site, petitioned the Agency for Toxic Substances and Disease Registry (ATSDR) to conduct a public health assessment of IEL. In 1989, ATSDR released a public health assessment of this site [1].

ATSDR is a member of the IEL Technical Information Committee (TIC). The TIC was established to review remedial design components and other technical issues at the site. ATSDR is addressing the radiological data in this health consultation because of agency involvement on the TIC and the concerns of CCLT that radioactive materials may be in the landfill. The Ohio Environmental Protection Agency (OEPA) and the USEPA collected the radiation data. For the OEPA, contractor services provided the radiological analyses. The USEPA National Air and Radiation Environmental Laboratory (NAREL) analyzed the radiological samples collected by USEPA. The sampling data reviewed for this health consultation were supplied to ATSDR by OEPA and USEPA.

Sampling at IEL included four quarterly rounds of both water and sediments collected from residential wells and monitoring wells during 1992 and 1993. Both sets of wells were sampled at different depths, designated shallow, intermediate, and deep. Some samples were field filtered; others were not. In addition the samples were not true split samples. ATSDR, however, believes the data are of sufficient quality to evaluate the information for public health implications (see appendix).

The analyses included gross alpha radiation, gross beta radiation, and tritium (H-3) using the laboratory procedures developed for the Safe Drinking Water Act (SDWA) [2]. Specific radioisotopic identification was either by gamma radiation spectroscopy or direct radiochemical analysis. The major naturally occurring radioisotopes detected included Uranium (U-238/235/234), Thorium (Th-232/230/227), and Radium (Ra-226/228). The other major radioisotope for which there were analyses was Plutonium (Pu-239/238).

ATSDR's top priority is to protect public health and the agency will determine if there is a public health hazard based on current levels of radiation. To make this determination, ATSDR addressed two questions related to IEL.

1. Are the current levels of radioactivity detected at IEL elevated (above background) and;
2. If the levels are elevated, what are the public health hazards associated with those levels of radioactivity in the landfill?

Discussion:

To review the information collected for this consultation, ATSDR examined the data on an individual well basis. This included the depth of the collected samples and when the samples were collected (quarterly rounds). Including field blanks, laboratory duplicates and other quality control and quality assurance samples, over 1,000 samples were analyzed through the joint efforts of OEPA and USEPA.

There are many methods to analyze the data. The final method used by ATSDR to analyze the data used the following procedure:

1. If the data reported was a negative value, then insert half the Minimum Detectable Activity (MDA).
2. If the data were below the detection limit, but greater than a reported zero, use those data as reported.
3. If the data reported were zero, then data were handled as in #1.

ATSDR chose these procedures because they result in an overall higher arithmetic mean and are therefore more conservative (protective of public health) than other means of analysis. Discussions of these analyses, the sources of background radiation and observations of the data sets collected at IEL are included in appendices I and II to this health consultation.

Gross alpha and beta results At IEL, the average gross alpha activity and average gross beta activity did not exceed 15 picocuries per liter (pCi/L). In order to make public health determinations based on the absorbed dose of radiation, the specific isotope and energy of the radiation are necessary. Since gross alpha and gross beta are not isotope-specific, no public health determinations or dosimetric evaluations can be made (Appendix III).

Tritium (H-3) In the USEPA samples, residential wells and monitoring wells were analyzed for H-3 using the SDWA approved method. In all cases, the H-3 concentration did not exceed 300 pCi/L. However, in the December 1992 round collected by OEPA, the mean tritium levels in all monitor wells were approximately 2000 pCi/L. The maximum value reported was about 4,000 pCi/L. This was about ten times the values reported by USEPA.

The current MCL for tritium in drinking water is set at 20,000 pCi/L. In the proposed regulations, this MCL would be increased to 60,000 pCi/L. Therefore, the levels of tritium reported by OEPA and USEPA are not considered a public health problem (Appendix IV).

Uranium and thorium in groundwater The groundwater data from USEPA are shown in Tables I, II, and III. Ohio EPA groundwater results are in Tables IV, V, and VI. Table III shows the absolute ranges and arithmetic mean of all wells and all rounds for the uranium, thorium, and radium isotopes. The current and proposed Maximum Contaminant Level (MCL) is also given for comparison to drinking water standards. From the information supplied by Hess, NCRP, and Longtin [3,4,5], the amounts of uranium and thorium detected in groundwater at IEL are equivalent to normal background levels. Based on these results, the levels of uranium and thorium are not considered a public health concern. Because of the method used to evaluate the data, radium in monitoring wells, but not in residential wells appears to be elevated above the current MCL. If those values below the MDA are not included in the analyses, radium is clearly elevated above the current MCL. However, monitoring wells are not a potable water source and thus radium is not considered a contaminant of concern for exposure (Appendix V).

Table I. Radiation levels[1] in groundwater from residential wells[2] as reported by US EPA.

Well	Alpha	Beta	Tritium
8	2.1	5.8	224
22	1.8	1.3	88
42	1.7	4.6	131
42D	2.7	3.4	147
48	1.2	2.2	124
52	5.0	6.2	180
54	1.8	2.0	123
62	1.4	1.9	140
64	1.0	2.8	93
64D	2.0	2.6	143
70	1.4	1.8	274
72	3.1	2.6	130
SOD Farm	2.0	2.9	293
All res wells	2.1	3.1	143

1. Levels are in picocuries per liter.
2. The values shown are the arithmetic means of all sampling points collected during the four sampling rounds.

Table II. Radiation Levels[1] in Monitoring wells[2].

Well	Gross Alpha		Gross Beta		Tritium	
	Arith.[3]	Geo.[4]	Arith	Geo.	Arith.	Geo.
Shallow	6.3	1.5	10.5	3.2	143	120
Intermediate	1.8	1.5	6.1	3.7	216	174
Deep	1.8	1.6	4.5	3.2	164	133

1. Levels are expressed in picocuries per liter.
2. Data from US EPA rounds 6 through 9.
3. Arithmetic mean of all samples
4. Geometric mean of all samples

Table III. Range of radionuclides in groundwater from IEL[1]

Radioisotope	Range (pCi/L)	Mean[2] (pCi/L)	MCL[3] (pCi/L)	
			Current	Proposed
Ra-226	1.1 to 9.5	6.3[4]	5	20
Th-232	8.3E-5 to 8E-2	1.6E-2 5E-3	none	92
U-234	0.06 to 3.3	0.74 0.34	30[5]	UD[6]
U-235	3.1E-3 to 9.6E-1	0.095 0.04	30	UD
U-238	5.2E-2 to 1.76	0.41 0.34	30	UD

1. Data from USEPA. The ranges and arithmetic mean values are from all wells (monitoring and residential wells), all sampling rounds.
2. The mean value does not include those samples in which the reported value was a negative number or the reported value was zero. Where two values are given, the first is for all wells, the second for residential wells only.
3. Maximum Contaminant Level for public drinking water supplies.
4. For Ra-226, the geometric mean was 5.7 pCi/L.
5. Current limit does not separate individual uranium isotopes.
6. Under development

Table IV. Groundwater monitoring well data from Ohio EPA[1]

Isotope	May 1992	August 1992	December 1992	May 1993
Alpha	10.4	146	10.8	15.3
Beta	20.2	133	38.9	82.9
Tritium	490	NR[2]	3312	761

1. Data in picocuries per liter and averaged across all sampling rounds from all wells.
2. Not reported

Table V. Monitoring well data by depth from Ohio EPA[1]

Radiation parameter	MW 17		MW 23		MW 27	
	Shallow	Deep	Shallow	Deep	Shallow	Deep
Alpha	81	2.3	193	4.3	222	NR
Beta	119	NR[2]	210	NR	133	NR
Tritium	3312	366	NR	597	4012	NR

1. Data in picocuries per liter.
2. Not reported

Table VI. Ohio EPA results of Residential Well Monitoring[1]

Well	Gross Alpha	Gross Beta	Tritium
RW 42	3.8	9.4	411
RW 48	3.5	NR[2]	375
RW 52	5.9	6.9	403
RW 64	2.1	NR	NR

1. Values are in picocuries per liter and are the averages of the quarterly rounds.
2. Not reported.

Filter results In surface soils collected in Ohio, Myrick, et al., [6] reported that the activity of U-238, Th-232, and Ra-226 was essentially 1 pCi/g. ATSDR compared the activities detected on the filters to the results of the Myrick, et al. studies. Table VII gives the quarterly analysis of the filter data supplied by USEPA. The expected ratios, from the secular equilibrium calculations, are also shown in the table. Based on these numbers, the radioactivity ratio per gram of sediment on the filters represents the expected distribution in nature. Although the U-238/U-235 ratio is less than expected, this may be related to solubility differences between U-235 and U-238. These results from analyses of filter data suggest that the levels of radioactivity found in the landfill are naturally occurring and present at expected levels (Appendix VI). Furthermore, a detailed study of these decay products can explain the elevated gross alpha and gross beta radiation measured in landfill wells (data not shown). Briefly, during the decay of U-238 to Radon-222, a gas, 4 alpha particles and 3 beta particles are emitted. In the case of U-235 decaying to Radon-219, there are 4 alpha particles and 3 beta particles. When Th-232 decays to Rn-220, there are 3 alpha particles and 2 beta particles. In an ideal setting and secular equilibrium in place, the decay of 1 pCi U-238 atom could release 4 pCi of alpha particles and 3 pCi of beta particles. This reasoning can be used to explain the elevated gross alpha and gross beta radiation.

Table VII. Isotopic ratio of Uranium and Thorium series radionuclides detected on filters from monitoring wells[1].

Round	U-238/Ra-226	U-235/Th-227	Th-232/228	U-238/235
6	0.7	0.2	0.58	12
7	1.3	0.93	0.88	15
8	0.72	0.48	0.87	13
9	0.6	0.7	0.9	13
Mean	0.83	0.58	0.81	13.05
St. Dev.	0.32	0.31	0.15	1.33
Expected[2]	1.0	0.98	0.8	22.7[3]

1. Data from USEPA.
2. Determined by calculating the secular equilibrium ratio of each radionuclide series.
3. The presumption was made that there is no differences in solubility of the isotopes.

CCLT expressed concern that plutonium radioisotopes were present in landfill samples. Of the samples analyzed, or reanalyzed, by NAREL, the plutonium in water and on the filters was always below the detection limit by at least a factor of two. Because the reported values were below the detection limits, no additional data review by ATSDR was necessary.

Summary of Health Effects Discussion Based on the data supplied and analyzed by ATSDR, the levels of radioactive materials detected at IEL as uranium, radium, and thorium are present at natural levels. Since the radioactivity at IEL is representative of naturally occurring levels in surface soils and presumably the sediment, and since the monitoring wells are not used as a source of potable water, no adverse health problems would be expected. These radionuclides are part of the normal dietary uptake in humans, and few if any health studies have been reported [7].

Similarly, one would not expect the radioisotopes to be hazardous using the classification of Resnikoff [8], who introduced the term "hazardous life." He defined the term as "the time required for a radioactive substance to become non-hazardous, defined here as the time for the radioactive concentration to reach 100 times maximum permissible concentration." In the report "Living Without Landfills," this is referred to as the "maximum permissible concentrations allowed by the Nuclear Regulatory Commission, as specified in its 10 CFR Part 20 regulations."

Table VIII gives the old limits of 10 CFR 20, the new 10 CFR 20 public limits, the hazardous life concentrations, and the levels found at IEL. The current levels of radionuclides at IEL are below, sometimes by orders of magnitude, the old and new Nuclear Regulatory Commission limits and the hazardous life concentration as proposed by Resnikoff [8]. This also would suggest no adverse health effects would be expected.

Table VIII. Radionuclide limits of the Nuclear Regulatory Commission and the hazardous life concentrations.

Radioisotope	NRC-1[1]	NRC-2[2]	Haz-Life[3]	IEL[4]
H-3	30 E 6	1 E 6	30 E 8	< 300
Ra-226	30	60	3 E 3	9.5
Th-232	2 E 3	30	2 E 5	8 E -2
U-235	3 E 4	300	3 E 6	0.96
U-238	4 E 4	300	4 E 6	1.76
Pu-238	5 E 3	20	5 E 5	BDL[5]
Pu-239	5 E 3	20	5 E 5	BDL

1. Expressed as picocuries per liter of water, most conservative value for public exposure reported in the 10 CFR 20 in effect in 1987.
2. New 10 CFR 20 [56 FR 23360] expressed as picocuries per liter of water, most conservative value for public exposure.
3. The hazardous life concentration as defined by Resnikoff [7] and calculated by multiplying the numbers in the NRC-1 column by 100.
4. Maximum concentration at the landfill in picocuries per liter found at the landfill.
5. Below detection limit of system.

Conclusions

Based on the information and data provided to ATSDR, the IEL concentrations are indicative of environmental background levels of radioactivity. More importantly, based on current scientific knowledge, the levels are not of public health concern. ATSDR makes the following conclusions of the radiation data collected at the Industrial Excess Landfill during the 1992-1993 sampling period:

- The levels of radioactivity at the IEL site are in the ranges representative of background levels both in the state of Ohio and other areas around the United States.
- Although the levels of gross alpha radiation and gross beta radiation appear to be elevated, an indepth analysis of the radiochemical data explain these apparent elevated levels as uranium and thorium decay products.
- Tritium levels are comparable to surface water samples collected throughout the country. The detected levels are 100 to 300 times lower than the current or proposed MCL, respectively.
- The levels of radiation at IEL are not a public health concern. No adverse health effects would be expected at the levels present and there are no health studies in the scientific literature available to substantiate such claims.

Recommendations

With the issuance of this health consultation, ATSDR completes its evaluation of potential radioactive contamination and radioactive materials in the Industrial Excess Landfill.

Because of the lack of radionuclides at levels of public health concern, no recommendations for additional sampling for radionuclides are made. However, ATSDR will review additional information if available.

Paul A. Charp, Ph.D.
Senior Health Physicist

Laura Barr
Environmental Health Scientist

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3. Memorandum from James J. Mueller, Controls for Environmental Pollution, Inc. to Eda Williams, Belz Analytical Laboratories dated November 22, 1991.

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8. National Research Council (1988). Health risks of radon and other internally deposited alpha-emitters - BEIR IV. Washington, DC: National Academy Press 602 pp.

Appendix I

I. Background Radiation

Natural decay chains of the uranium isotopes and thorium isotopes account for most of the naturally occurring radioactivity in the environment. Other naturally occurring sources contributing to background radiation include, but are not limited to, potassium-40, vanadium-50, rubidium-87, and cosmic ray interactions. Contributions from fallout include but are not limited to plutonium isotopes, tritium, radioiodines, radiocesium, and radiostrontiums. Many of these fallout products are now considered background products because of widespread (global) occurrence. In groundwater, background levels of radioactivity can vary depending on fallout from atmospheric nuclear testing, ore materials, and aquifer properties.

To determine if the radioactivity at IEL is above background levels, there are national and local databases for estimating the background radiation near IEL. It is important, however, to recognize that there are limitations to these databases. Some databases ATSDR used supplied only an average but not how that average varied (deviated) and some data were not collected in the state of Ohio or in the vicinity of IEL. ATSDR recognized the limitations but the data were considered sufficient to estimate the potential effects on public health. For the issues of public health and calculations of radiological dose, the total amount of radioactivity present can be used to estimate the total dose and ultimately potential health effects.

Databases considered by the TIC included the US Geological Survey (USGS) regional aquifer database (RASA) used to determine the age of groundwater by analyzing tritium (H-3), the state of Ohio Model State Information System (MSIS) for compliance with the Safe Drinking Water Act (SDWA, Public Law 93-523), and the USEPA Environmental Radiation Ambient Monitoring System (ERAMS). Table A1 lists the ranges of radioactivity in these databases.

The USGS report of August 13, 1993, suggested the possibility that certain wells could be used as background wells [1]. Additional monitoring of local groundwater systems is planned for 1994 to verify groundwater flow directions. Based on the USGS report, the monitoring wells ATSDR considers background are 12 and 20, located north and east, respectively, of the landfill. Well 12 is hydraulically upgradient from IEL and Well 20, east of Metzger's Ditch, is a natural groundwater discharge area. Well 20 is less suitable, however, because it may be influenced by dredging or by contamination from the landfill if the ditch overflowed, passing into the well between the casing and the soils. The radiation levels in these wells are given in Table AII.

Table AI. Representative values from several databases

Database	Parameter	Range
RASA[1]	Tritium	64 - 140 pCi/L
MSIS	Gross beta[2]	3 - 18 pCi/L (6.6 avg.)
MSIS	Gross alpha[3]	4 - 11 pCi/L (4.1 avg)
Myrick, et al.[4]	Ra-226	1.5 ± 0.93 pCi/g
Myrick, et al.	U-238	1.4 ± 0.79 pCi/g
Myrick, et al.	Th-232	1.0 ± 0.5 pCi/g
ERAMS[5]	Alpha	ND[6] - 0.25 pCi/L
ERAMS	Beta	1.95 - 3 pCi/L
ERAMS	Tritium	250 - 337 pCi/L

1. USGS regional aquifer database.
2. Compliance monitoring, MDA estimated at 3 pCi/L.
3. Compliance monitoring, MDA estimated at 4 pCi/L. The data were collected from Stark, Summit, and Portage counties that surround the landfill.
4. Myrick, T.E., Berven, B.A., and Haywood, F.F. (1983). Ohio surface soil data, arithmetic means only.
5. Environmental Radiation Ambient Monitoring System data covering 1979-1984 from 5 surface water sampling points in Ohio.
6. Non-detect

Table AII. Wells potentially suitable for background values[1]

Well	Gross Alpha	Gross Beta	Tritium
12	3.4 (ND - 3.8)	3.8 (ND - 4.62)	170 (ND - 330)
20	1.9 (ND - 2.36)	2.5 (1.2 - 33.4)	179 (ND - 260)

1. USEPA values are in picocuries per liter and represent the averages of all shallow, intermediate, and deep well samples. The ranges are given in parentheses; ND is below detection limit.

II. Observations of the data sets

Detection limits and counting statistics In the laboratory collection of data, computer programs are used to analyze the collected data. This becomes a problem when data sets contain negative numbers or if the data reported are below the detection limit. Normally, these would be classified as "non-detect" or "below detection limits."

In radiation detection, the lower limit of detection or minimum detectable activity (MDA) and the error in the counting depends on the sample matrix or composition, the type of radiation being detected, the sample counting time, and the mechanics of detection [2]. This is especially true in the analysis of environmental samples. Furthermore, each data point has an associated counting error called 2 sigma (2σ). Essentially this is the confidence level at which one is 95% assured that the reported value is truly representative of the results. In the analysis of environmental radioactivity, the amount of radioactivity is so low that the associated counting error can be quite high. Often, the IEL samples' 2σ error was greater than the reported measurement. One must remember, however, that this is not an error of the sample collection but of the sampling counting.

To reduce the associated counting error, the laboratory can count the sample for a longer period of time. However, increasing the time does not change the reported value but results in a lower counting error.

Environmental sample distribution At the November 18, 1993, TIC meeting, NAREL discussed the numerical distribution of the data. NAREL said that if the data were plotted from the lowest to highest value, a normal distribution was not obtained. That is, the determinations did not fit a "bell shaped curve." The distribution represented a "log-normal" distribution where most of the sample values were concentrated at the lower end of the distribution.

To illustrate the differences in the arithmetic means and the geometric means, figures (1-8) show the results of groundwater samples collected by NAREL during the four rounds. Figures 2, 4, 6, and 8 give the geometric means and the geometrical means are lower than the arithmetic values. To be protective of public health it would be more conservative to determine any potential health effects from the higher arithmetic values.

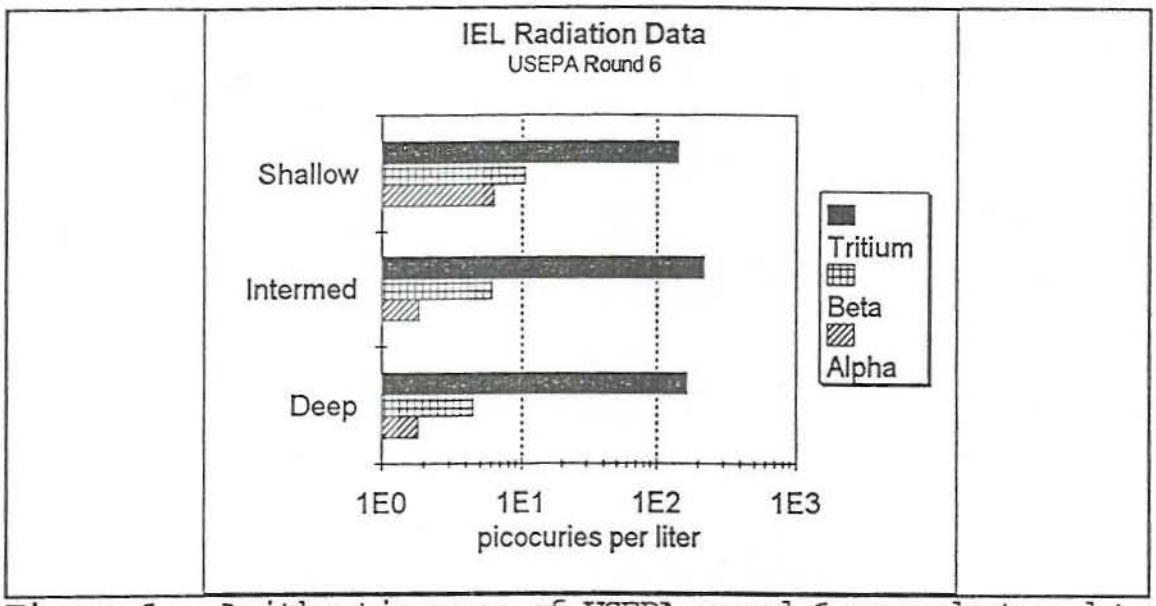

Figure 1. Arithmetic mean of USEPA round 6 groundwater data

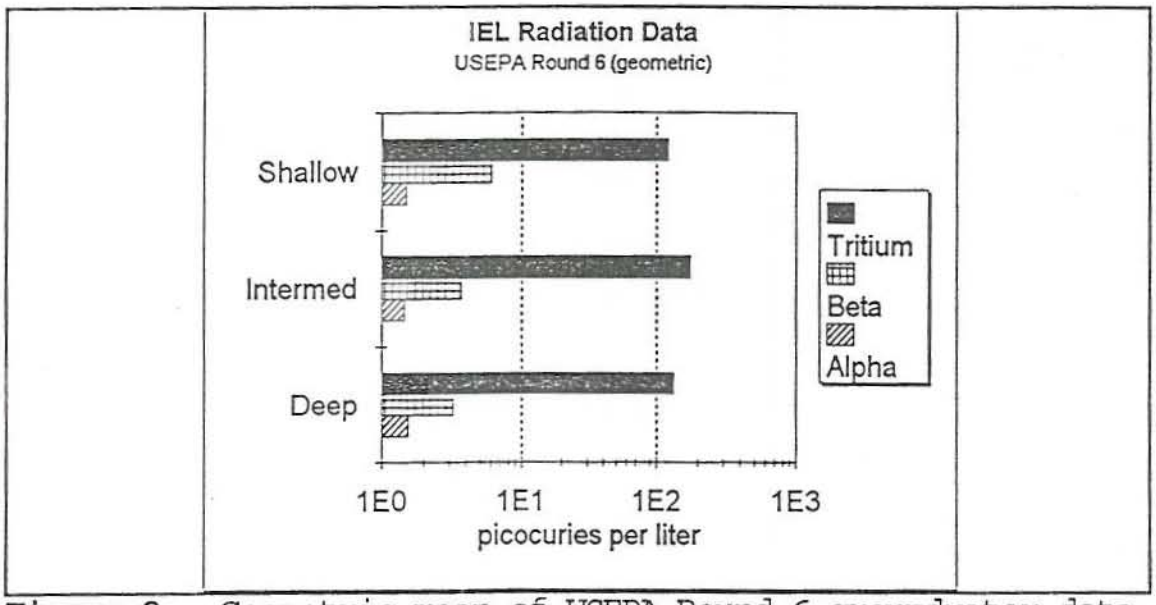

Figure 2. Geometric mean of USEPA Round 6 groundwater data.

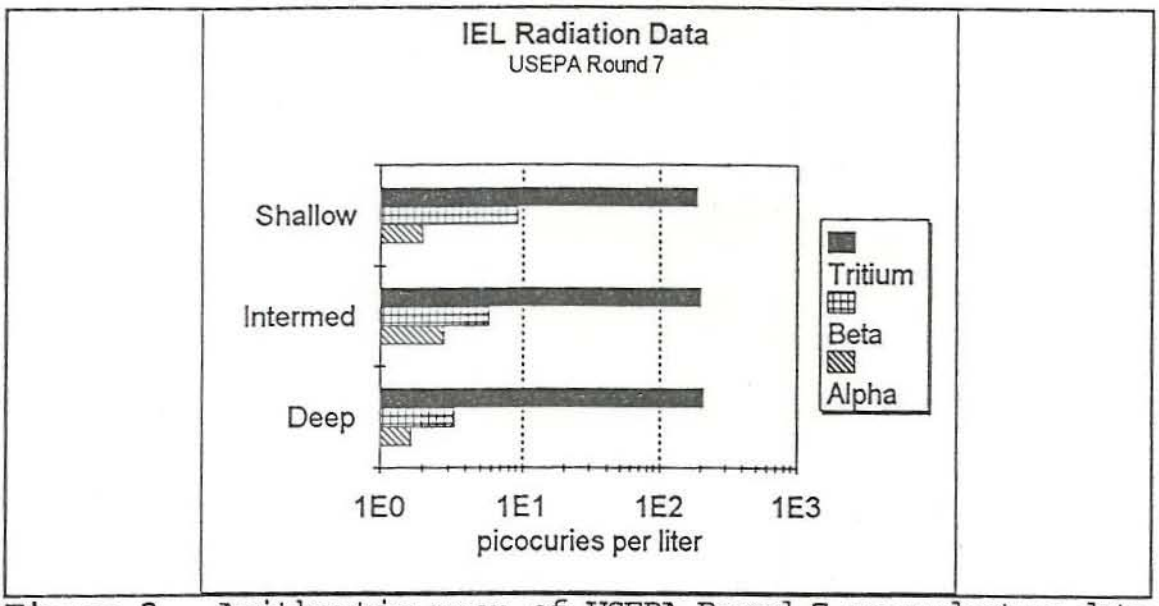

Figure 3. Arithmetic mean of USEPA Round 7 groundwater data

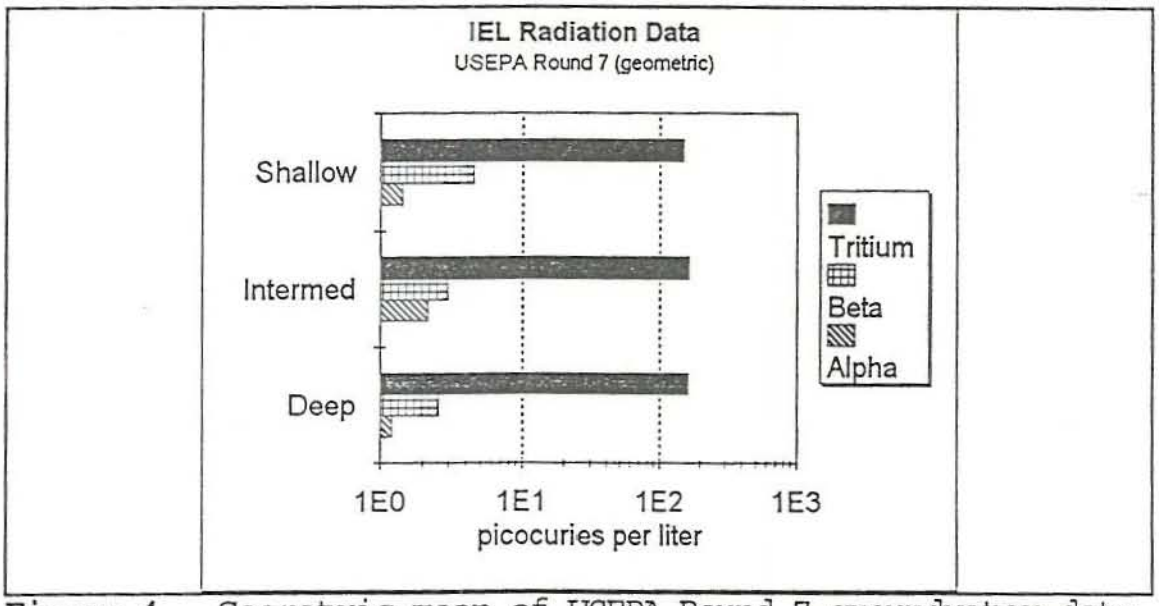

Figure 4. Geometric mean of USEPA Round 7 groundwater data

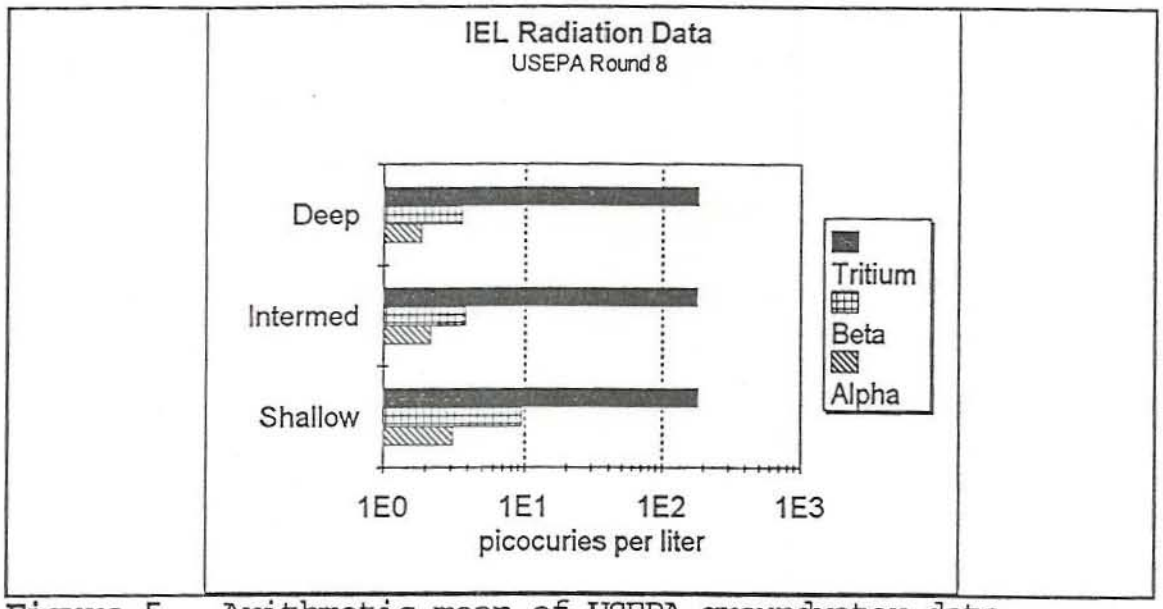

Figure 5. Arithmetic mean of USEPA groundwater data

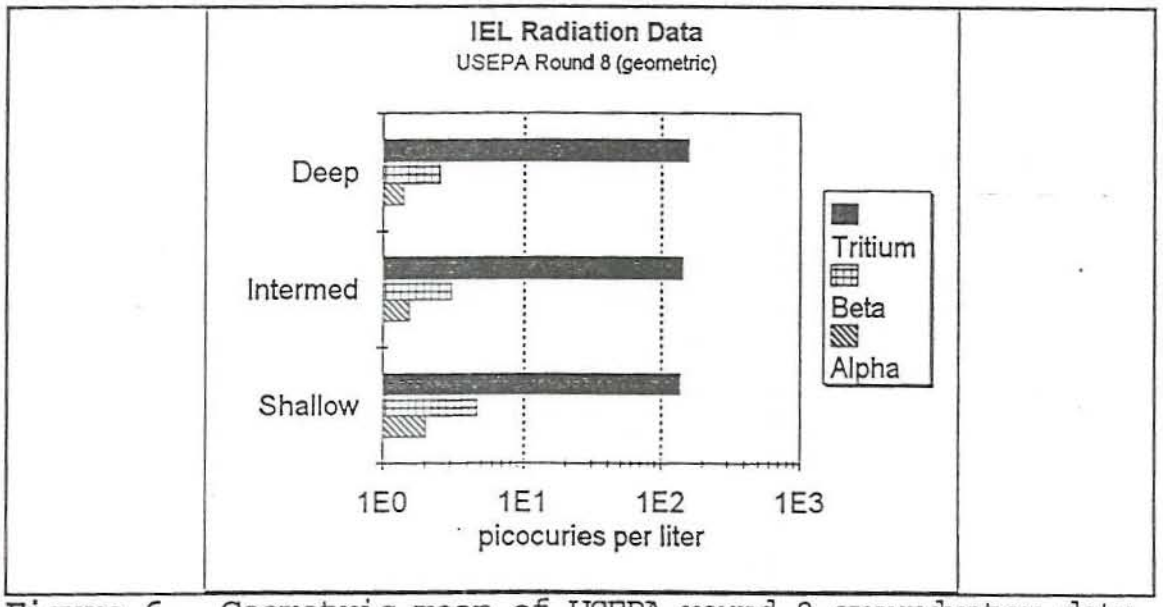

Figure 6. Geometric mean of USEPA round 8 groundwater data

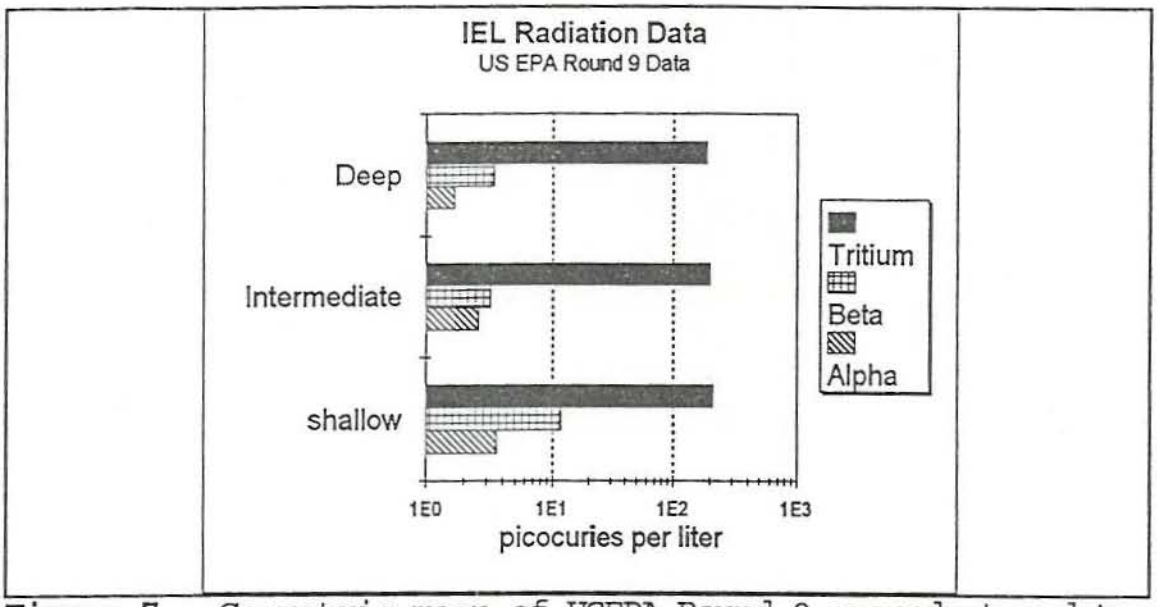

Figure 7. Geometric mean of USEPA Round 9 groundwater data

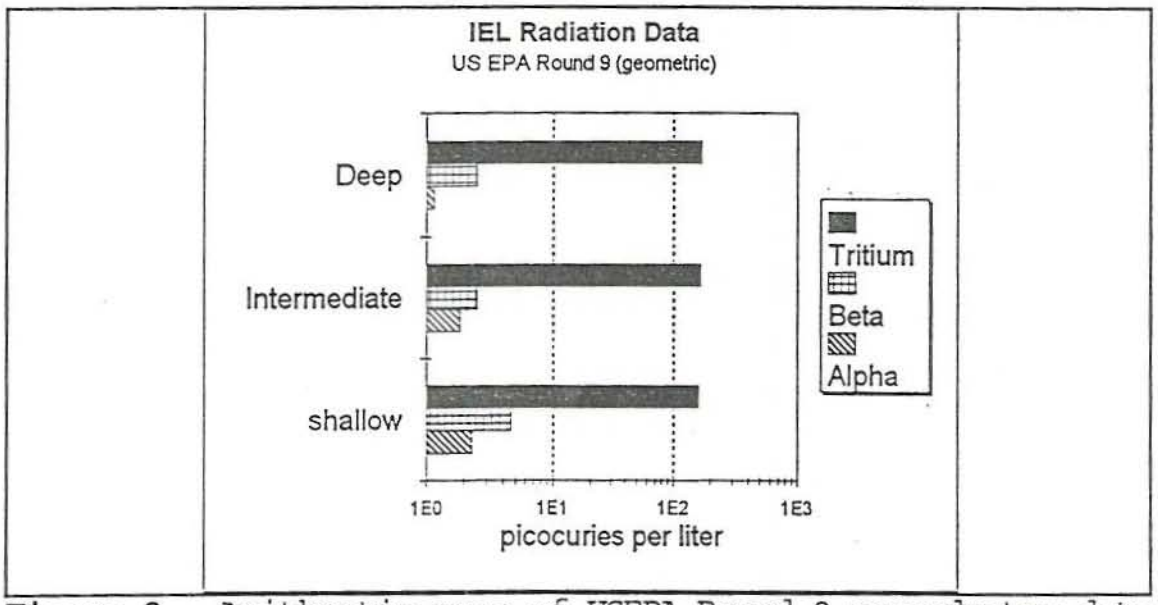

Figure 8. Arithmetic mean of USEPA Round 9 groundwater data

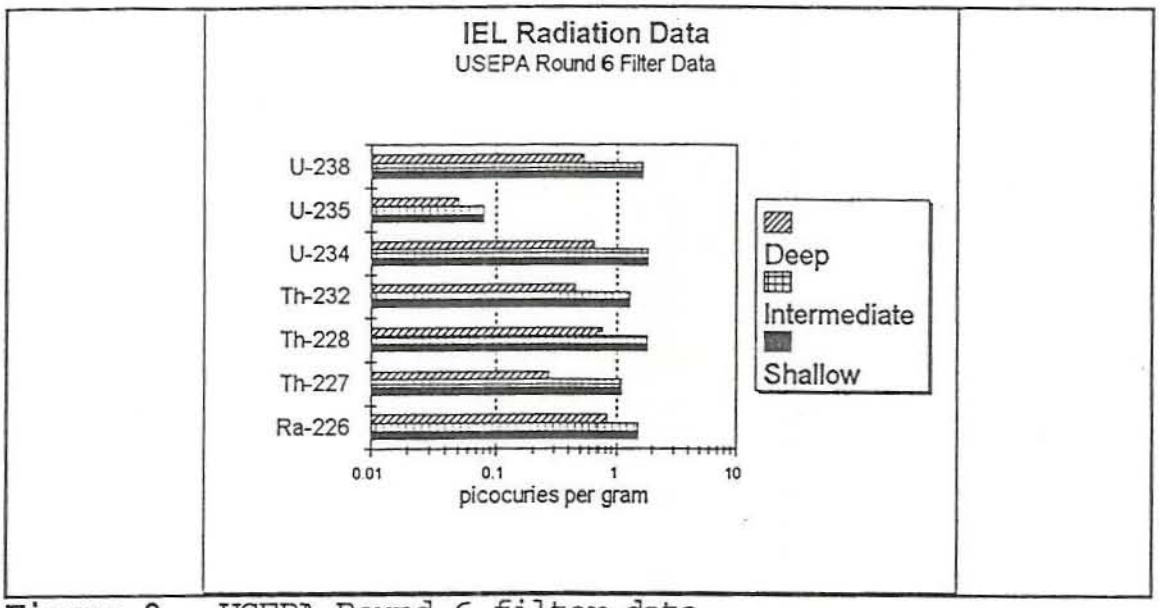

Figure 9. USEPA Round 6 filter data

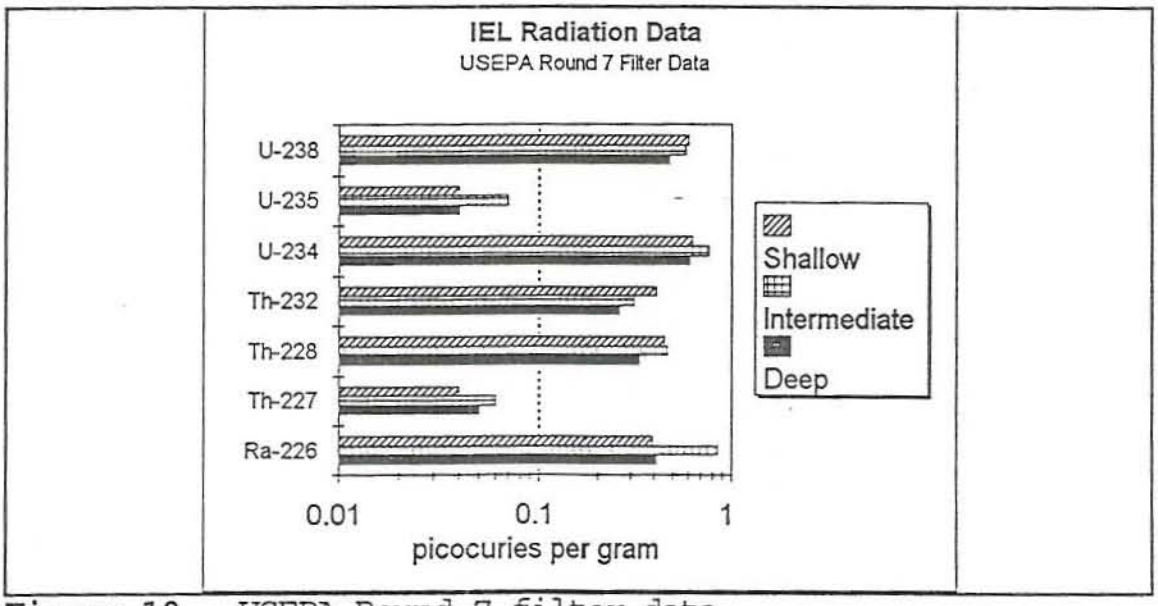

Figure 10. USEPA Round 7 filter data

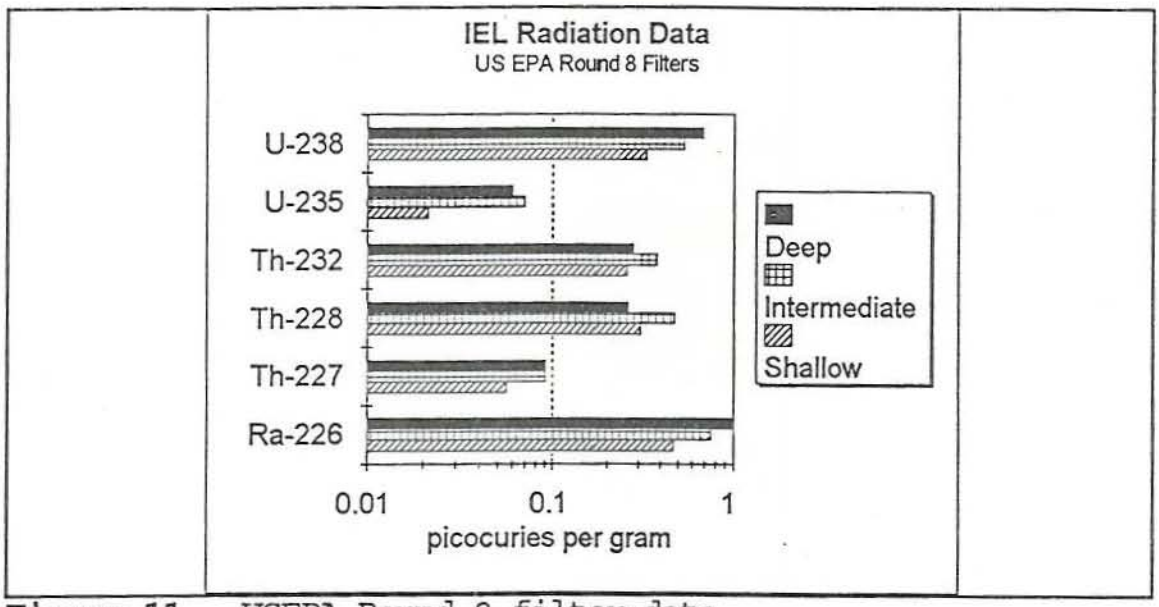

Figure 11. USEPA Round 8 filter data

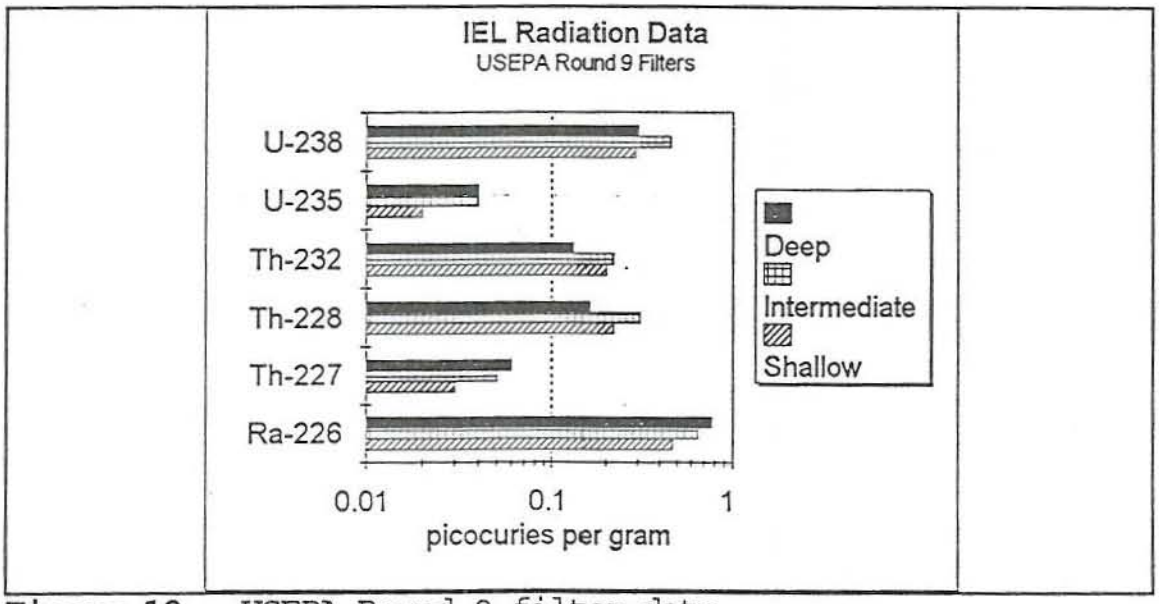

Figure 12. USEPA Round 9 filter data

Data values Because much of the data reported either were negative values or below the Minimum Detectable Activity (MDA), the question of how to analyze the data was raised by CCLT and their experts. The major concern raised was use of data below the MDA. ATSDR considered these possible analyses schemes before its final data review and analysis:

a. Only use data above the MDA;
b. If data were within 20% of the MDA, and if the reported value was greater than the 2σ error, use those data and those above the MDA.
c. If data were more than 20% below the MDA, use half the MDA.

Each of these procedures could artificially raise or sometimes lower the actual measurement from the IEL sampling stations. Therefore, ATSDR decided to analyze the data using the following procedure:

1. If the data reported was a negative value, then insert half the MDA.
2. If the data were below the detection limit, but greater than a reported zero, use those data as reported.
3. If the data reported were zero, then data were handled as in #1.

III. **Gross alpha and beta results** Analyses for these parameters are a screening tool under the SDWA. Under normal conditions, target levels are set up that, if exceeded, determine the need for additional analysis. In the SDWA, Primary Drinking Water Standards, the target level for gross beta is 50 pCi/L and for gross alpha, the SDWA screening value is as low as 15 pCi/L. If the screening values do not exceed these levels, no additional analyses are necessary.

IV. **Tritium** Tritium can be one of the most difficult environmental radionuclides to analyze. Because the radiation emitted is so weak, procedures must consistently be repeated and good laboratory techniques always used . Most tritium analyses reported by the OEPA were similar to those reported by USEPA.

There was one instance where the OEPA contract laboratory reported an extremely high tritium value, over 1,000,000 pCi/L. The laboratory performing these analyses provided the following information in a memorandum [3]:

> Five of six samples were clear, containing less than 500 pCi/L H-3. The one remaining sample was cloudy and was separately processed. This difference in processing included filtering the sample, addition of sodium hydroxide and potassium permanganate and distillation. The middle fraction of the distillate was collected and placed in a liquid scintillation counter. No sample counts were repeated because QA procedures were within the acceptable range. The results of this particular sample showed a H-3 range more than 1E6 pCi/L.

OEPA stated that the well showing the high tritium level on a previous round was a non-detect and the sample collected in the following round was also a non-detect. Furthermore, no quality control or quality assurance data were supplied. Therefore, OEPA has invalidated this particular sample. ATSDR also believes the sample to be a false positive because there was no need to filter then distill the sample. The SDWA protocols [4] do not require filtration. Also different types of filters may contain compounds that may react with liquid scintillation fluids used for aqueous samples resulting in spurious counts (laboratory experience of author). Distillation does not necessarily separate all components in a liquid system.

In comparing the tritium levels detected at IEL to other databases in this

health consultation, the levels at IEL are somewhat higher. However, the methods of analysis between the USEPA and USGS RASA differ. The USEPA follows the SDWA; whereas, USGS treats the samples differently, counts for a longer time and repeats the counts more than USEPA. Therefore, the USGS can measure a lower concentration of tritium. In the ERAMS database, tritium from surface water and groundwater supply systems has been reported at concentrations between 0.1 and 0.3 nanocuries per liter (100-300 pCi/L, including rounding errors). At IEL, USEPA reported no levels higher than 300 pCi/L and the USGS RASA database indicates levels around 140 pCi/L. In Table AII, well 12, the tritium level was 170 pCi/L and in well 20, the tritium level was 179 pCi/L. Therefore, it is ATSDR's opinion that the levels of tritium detected at IEL are similar to background levels.

V. **Groundwater results** The concentration of radioisotopes in groundwater can vary. Uranium solubility depends on the electrical charge (oxidation state) of the ion. In general the +4 state of uranium is insoluble; whereas, the +6 state is soluble, especially when complexed with carbonate ions. Hess, et al. [5] states that the solubility will depend, upon other factors, on the basic concentration of underlying rocks through which groundwater flows, and the amount of oxygen and chemicals in the water. As the oxidation states in the groundwater change, the degree of uranium solubility will change with the changing groundwater conditions. Thorium, like uranium, is very insoluble in water, but it has one oxidation state and is not soluble at low temperatures [5]. For uranium, the NCRP [6] reports that the nationwide average concentration in groundwater, based on 55,000 samples, is about 3.2 pCi/L. In the National Inorganics and Radionuclide Survey, Longtin reports the estimated uranium activity at 2.4 pCi/L [7]. For Stark County (site of IEL), the uranium was less than 0.08 micrograms per liter. This is approximately 0.1 pCi/L of total uranium. In Portage County that borders Stark County, the uranium concentration was about 0.16 pCi/L [7].

Under natural conditions, the presence of radium in groundwater depends on the amount of uranium containing rocks through which groundwater passes. Radium is rapidly absorbed to surrounding materials from groundwater and as such, does not collect in groundwater but is localized in the areas producing the radium [5]. Hess also says that the range of radium-226 in aquifers can range from 0 to 26 pCi/L [5]. In the NIRS database, about 1% of all samples exceeded 5 pCi/L radium [7]. At IEL, the average radium concentration was less than 10 pCi/L.

VI. **Filter Data** Radioisotopes can serve as "fingerprints" because during decay, the decay products only arise from the original material. For example, the decay of U-238 always leads to the production of U-234 and Ra-226 always produces Rn-222. Over time, the activity of the decay products will equal the activity of the original radionuclide present. In undisturbed nature, all decay products of U-238 are in equilibrium with the U-238. This is also true for U-235 and Th-232 decay products. This is called secular equilibrium and is an important component of the IEL data analysis. Therefore, once a quantity of radioactivity in the particular decay chain is known, the other activities can easily be calculated if secular equilibrium is believed to be present.

The procedures for the collection of the filtered samples have resulted in much disagreement by the concerned parties at IEL, especially CCLT. The information supplied to ATSDR from the Ohio EPA and their contractor did not state the weight of materials on the filter. Therefore, analysis of these data was not possible. Figures 9-12 show the USEPA analysis of the filters collected during the sampling rounds. The material collected was sediment from monitoring wells. Regardless of the amount of sediment collected during the filtration procedures, the sediment is expected to be uniform in composition (Maslia, ATSDR personal communication). The more sediment collected by filtration the more total radiation would be detected. However,

a comparison of the filters on a mass basis (activity per gram) supplies sufficient information for analysis.

VII. **Summary of Health Effects** For uranium, 1.5 bone sarcomas per million people upon the ingestion of 5 pCi of uranium per day over a lifetime of exposure has been estimated. The normal occurrence for bone sarcomas is 750 per million people [8]. The major health problem from exposure to uranium is kidney toxicity. This effect is thought to have its effect when the uranium concentration in the kidney reaches from less than 1 to perhaps 3 micrograms uranium per gram kidney weight [8]. In summary for uranium isotopes, the National Research Council states "that exposure to natural uranium is unlikely to be a significant health risk in the population and may well have no measurable effect" [8].

Three studies correlating radium content in drinking water with health effects have shown varied results. One study found elevated bone cancer, the second found elevated bladder, lung, breast cancers, and the last study showed elevated levels of leukemia. However, these studies do not agree with long term studies of the radium dial painters and other individuals exposed to high radium levels, as much as thousands of time more than in water [8]. The National Research Council believes "there is little evidence for an age or sex dependence of the cancer risk from radium isotopes" [8].

Studies involving environmental exposure to thorium were not found. The most epidemiological studies have involved Thorotrast (thorium dioxide) patients. Thorotrast is a colloidal suspension once used in medical radiography to enhance contrast. Because of the specific chemical nature of this material, the National Research Council states that "thorium in other forms will likely be quite different from the dose distributions associated with Thorotrast aggregates, and the risks values will also be different" [8].