UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

RECEIVED
REGION 1

MS 20
Q-5

March 23, 2000 2000 MAR 30 PM 2:50

MEMORANDUM TO: George Pangburn, Director
Division of Nuclear Materials Safety, RI

FROM: Larry W. Camper, Chief
Decommissioning Branch
Division of Waste Management, NMSS

SUBJECT: TECHNICAL ASSISTANCE REQUEST - II-VI INCORPORATED

As requested in the Technical Assistance Request (TAR), dated January 19, 2000, staff of the Office of Nuclear Material Safety and Safeguards (NMSS) has conducted a review of the Thorium-232 disposal limit proposed by II-VI Incorporated. In a letter to NRC dated November 16, 1999, (Attachment 1) the licensee provided a dose analysis (using RESRAD version 5.60) to justify their proposed disposal limit of 25 pCi/g each of Thorium-232 and its progeny.

NMSS staff has reviewed the analysis provided by the licensee and has concluded that it does not adequately model the dose that an average member of the critical group (i.e. a resident farmer) would receive. Staff conducted an independent analysis (see Attachment 2), which demonstrates that disposal of Thorium-232 at the proposed concentration (25 pCi/g) could pose an unacceptable risk to the public.

Staff determined that without restricting the distribution of materials within the capped landfill, a disposal limit of 4 pCi/g would meet NRC's dose criterion of 25 mrem/yr. However, the proposed release limit of 25 pCi/g could result in a dose less than 25 mrem/yr if restrictions are placed on the ultimate distribution of the disposal packages (see Attachment 2).

Attachments:
1. November 16, 1999 II-VI letter to NRC (ML003673673)
2. Staff Analysis of II-VI model and request

License No. STA-1455
Docket No. 040-8868

CONTACT: Eric Pogue, NMSS/DWM
(301) 415-6064.

127520

NMSS/RGN-002

TECHNICAL ASSISTANCE REQUEST
II-VI INCORPORATED
REVIEW OF RESRAD ANALYSIS

INTRODUCTION

II-VI Incorporated filters liquid effluent to remove hazardous materials prior to release of the water to the sewer. Small quantities of thorium build-up in the filtercake, which has previously been disposed of in an industrial landfill. Currently the licensee is holding such material as a result of recent enforcement action.

II-IV wishes to amend its License No. STA-1455 to permit the disposal of solid materials (i.e., soils and filtercake). II-VI has requested a disposal limit of 25 pCi/g each of Thorium-232 and its progeny. In a letter to NRC dated November 16, 1999, the licensee provided a dose assessment to justify their proposed disposal limit.

Staff has performed an independent dose assessment to evaluate the II-VI analysis. A preliminary screening analysis using DandD (Version 1.0) and a second more thorough analysis was performed by the staff using RESRAD (Version 5.95)was performed. In both cases staff's modeling resulted in significantly larger doses than the dose which II-VI calculated using RESRAD (Version 5.60). Staff examined the differences between the Licensee's and NRC's modeling and concluded that II-VI did not adequately account for the exposure an average member of the critical group would receive (specifically from material exhumed as part of the resident farmer scenario). Finally, staff explored alternatives whereby II-VI could achieve the 25 mrem/yr dose criterion. Note that 25 mrem/yr (the value from the License Termination Rule), rather than the 1 mrem/yr referenced by II-VI, is the dose criterion that the proposed disposal must comply[1].

AVAILABLE INFORMATION

Inventory

II-VI supplied information on the quantity of the proposed disposal. At a maximum, II-VI will dispose of 10 waste containers per year, for 30 years at an industrial landfill. The material will be placed in 30 cubic yard containers, resulting in a maximum disposal of 6,881 m^3. At a concentration of 25 pCi/g this equates to a disposal 0.258 Total Curies.

Disposal Limit Requested	# of containers (over 30 years)	Total Volume	Total Activity (x 37,000=MBq)
25 pCi/g	**300**	**6,881 m^3**	**[1]0.258 Curies**

---

[1]In the July 21, 1997 Federal Register (62 FR 39058) NRC stated its intent to utilize the 25 mrem/yr dose criterion to assess 10 CFR 20.2002 disposals.

Waste Facility

All of the contaminated material will be transferred to a single industrial landfill. For conservativeness the licensee has assumed that all of the material would be disposed of in a single continuous volume measuring 1,146 m^2 by 6 m deep. At the time of closure the landfill will be capped with a 2 m cover with a density of 1.5 g/cm^3. The licensee did not provide any site specific information (e.g. meteorologic or geologic data).

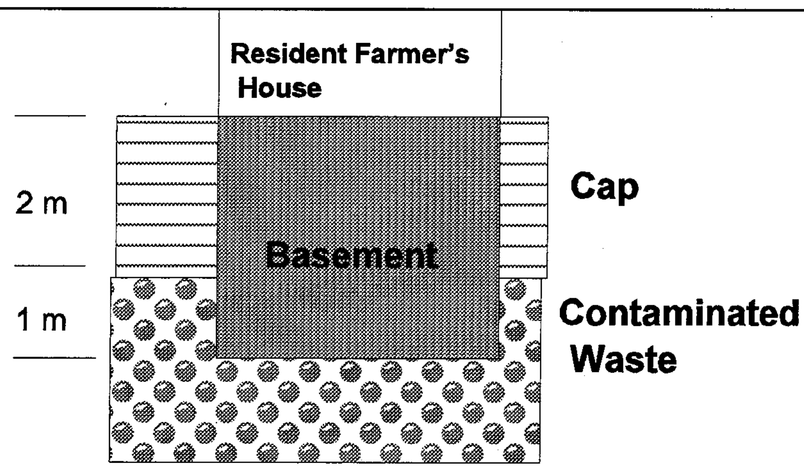
Scenario Definition

Both II-VI and staff assumed a resident farmer scenario. With the exception of Radon, which II-VI accounted for unnecessarily (*see* below and also 62 FR 39083), the following exposure pathways were utilized by both II-VI and Staff:

Exposure Pathways:
- External gamma
- Inhalation
- Plant ingestion
- Meat ingestion
- Milk ingestion
- Aquatic food ingestion
- Drinking water ingestion

Radon is excluded from consideration under the license termination rule primarily because of the difficulty in distinguishing radon resulting from site activity from background radon. In addition it is difficult to predict design features of future building construction, which will greatly affect doses someone will receive.

In the residential farmer scenario it is assumed that someone resides in a house atop the contaminated area and consumes food grown on the site. It is also assumed that the hypothetical future resident farmer will excavate a volume of 600 m^3 in building a foundation for their house. The top 2 meters of this excavated volume are assumed to be cover material, while the bottom 1 meter would be disposed waste (see below).



Schematic of Waste exhumed by residential farmer

Of the 600 m^3 exhumed in the scenario, the disposed waste accounts for only 200 m^3. However, the scenario assumes that this material, which would otherwise be "shielded" by a 2 m cap, is then distributed over a large area at the surface. This results in a member of the critical group receiving significant exposure to the waste through plant and animal uptake, soil ingestion, and external gamma radiation (significant for Th-232). Note that all of these pathways would be negligible if the material remained shielded and at depth.

While II-VI stated they used the resident farmer scenario for their analysis, they did not include in their model the exhumation of any contaminated material.

SCREENING ANALYSIS WITH DANDD

Initially staff performed a screening analysis using the DandD computer code (Version 1.0). Screening analysis with DandD relies on the use of default values, predefined models, and a predefined scenario (the resident farmer). The result of the screening analysis is expected to provide a prudently conservative estimate of the dose; that is, an overestimation of the actual dose that individuals might receive. Screening analyses are performed in DandD using only the source inventory or concentration of a burial or proposed burial. The staff analysis used the concentration value of 25 pCi/g for Thorium-232 and each of its progeny that was requested by the licensee.

Because the proposed burial will have contamination below the top 0.15 meters and the waste will be covered with a 2 m cap, the conceptual model is not entirely consistent with the features of the site . Accordingly, an approach termed the "Dual Simulation Approach" (see the guidance document "Preliminary Guidelines for Evaluating Dose Assessments in Support of Decommissioning")was utilized.

In the dual simulation analysis it is assumed that the activity is uniformly distributed over the volume of contaminated soil and interspersing clean soil. Further, consistent with the resident farmer scenario, it was assumed that a volume equivalent to the size of the basement is excavated. This excavated material is assumed to be spread out over the land surface to a depth of 0.15 m. For the analysis there are two different concentrations, $Conc_1$ and $Conc_2$. $Conc_1$ represents radionuclides mixed with the cover material and spread out over the land. $Conc_2$ represents the concentration of the remaining radionuclides left in place (i.e., in the waste but not excavated). The two contaminated zones will not represent the same exposure to the hypothetical farmer. The farmer can be exposed through all pathways from the top zone (at concentration $Conc_1$); however, the farmer's exposure to the second zone will be limited primarily through what is leached out and reaches the ground water. Because of the two concentrations and different exposure pathways associated with each, this conceptual problem will require two simulations with the DandD code. The first simulation was used to evaluate exposure from contaminants spread out over the land surface. For this first simulation all exposure pathways are considered with the exception of drinking water and irrigation (these will be covered in the second simulation). To exclude the drinking water and irrigation pathways, the following parameters were set to zero: water ingestion, domestic use, infiltration rate, and irrigation rate. The following approach was used to calculate the source concentration for this first simulation:

If $T_c + T_w > 3$,

$$\text{Conc}_1(\boldsymbol{i}) = \frac{\overline{Conc(i)}(3 - T_c)}{3}$$

If $T_c + T_w < 3$,

$$\text{Conc}_1(\boldsymbol{i}) = \frac{\overline{Conc(i)} * T_w}{3}$$

where:

$\overline{Conc_1(i)}$ = average concentration of radionuclide i from measurements = **25 pCi / g**

$Conc_1(i)$ = concentration of material on the surface = **8.33 pCi / g**

T_c = thickness of cap = **2 m**

T_w = thickness of contamination = **6 m**

In the above formulas, the cap and waste are both assumed to be represented by soil at a density of 1.431 g/cc (the DandD default). In addition, the basement height was assumed to be three meters. The cultivation area (Ar) parameter in DandD was set to 4000 m^2 (i.e., 600 m^3 divided by 0.15 m). The area of the hypothetical house was again assumed to be 200 m^2.

The second simulation was used to evaluate exposure from the remaining inventory, which could leach into the ground water. Because we are primarily interested in exposure from contaminated ground water, several parameters were set to zero in order to eliminate or reduce the exposure from the other pathways (i.e., external, inhalation, plant ingestion, and resuspension). Accordingly, the following parameters were set to zero for the second simulation: floor dust, resuspension factor, indoor dust, outdoor dust, gardening dust, indoor breathing, outdoor breathing, gardening breathing, time spent gardening, time spent outdoors, and soil ingestion rate. In addition, the indoor shielding factor should be set to 1.0 and the plant mass loading factor was set to 0.0011 (the smallest value allowed in DandD)[2]. II-VI's requested disposal limit (i.e., 25 pCi/g) was used as the source concentration for the second simulation.

For this second simulation, we did not account for the activity removed for the first simulation because irrigation and drinking water are excluded in the first simulation. Accordingly, the whole activity is used in evaluating impacts from exposure from these pathways in the second simulation.

The total dose for the dual simulation approach was obtained by summing the dose from the two simulations.

---

[2]It should be noted that even with this small mass loading factor, the agricultural pathway was a dominant pathway. Accordingly, the dose from the agricultural pathway were subtracted from the total dose for the second simulation.

The results from the analyses are as follows:

Simulation 1	Simulation 2*	Total Dose*
217 mrem/yr**	**617 mrem/yr**	**834 mrem/yr**

*Dose from the agricultural pathway in the second simulation has been subtracted out
**note to convert to metric: mrem x .01 = mSv

With a dose of 834 mrem/yr, to an average member of the critical group, the model did not pass screening.

GENERIC ANALYSIS WITH RESRAD

Staff Analysis

Because the screening analysis with DandD results in a dose exceeding the 25 mrem/yr criterion, more site-specific (site-related) analyses were performed using RESRAD (Version 5.95). RESRAD is the same code used by II-VI in their analysis. Using the same code allowed greater insights into II-VI's analyses. Further, because RESRAD allows the user to input information on the area and thickness of the contaminated zone (i.e., these are not fixed, although defaults are provided) the geometry of the contamination zone can be more truly represented.

A two-simulation approach was used similar to the dual simulation approach used with DandD where a limited volume of contaminated material is assumed to be excavated by someone building a house basement. This excavated material is assumed to be mixed with the existing cap and spread out over the land, where the resident farmer grows his crop. It is assumed that 600 m^3 of waste is brought to the surface and spread out over an area to a depth of 0.9 m. For the first simulation, we are interested in the dose from exposure to the material brought to the surface, such as, direct gamma radiation, inhalation, soil ingestion, and plant ingestion (excluding irrigation with contaminated water). Exposure from ground water, irrigation, and aquatic use is considered in the second simulation. Accordingly, the drinking water and aquatic pathways were switched off for the first simulation. In addition, the irrigation rate was set to zero. The source concentration for this first simulation was the same as the concentrations used for the first simulation of the DandD dual simulation analysis. The area used in the first simulation was 700 m^2 (i.e., 600 m^3 divided by 0.9 m). The assumed thickness of contamination was 0.9 m.

The second simulation looked at effects from exposure from the remaining waste. The primary environmental transport pathway for this remaining waste will be ground water. For the second simulation the external gamma, inhalation, and soil ingestion pathways were switched off. In addition, the mass loading for foliar deposition parameter was set to zero. Further, unlike for DandD, the contaminated zone was assumed to be covered for the second simulation.

Because RESRAD is designed for site-specific analysis, a single default parameter set has not been established for performing generic screening analyses. Although RESRAD has default parameters, these parameters may or may not be suitable or provide a conservative estimate of the dose for any given site. The following default parameters, taken from DandD were used Staff's RESRAD analyses:

Parameter	**Value**	**Units**
Inhalation rate	1.169e+04	m^3/y
Mass loading for inhalation	3.14e-06	g/m^3
Shielding factor for external gamma radiation	0.5512	
Fraction of time spent indoors	0.6571	
Fraction of time spent outdoors	0.1101	
Fruits, vegetables, and grain consumption	112	kg/y
Leafy vegetable consumption	21.4	kg/y
Milk consumption	233	L/y
Meat and poultry consumption	65.1	kg/y
Fish consumption	20.6	kg/y
Soil ingestion	18.26	g/y
Drinking water intake	478.5	L/y
Contamination fraction of drinking water	1	
Contamination fraction of livestock water	1	
Contamination fraction of irrigation water	1	
Contamination fraction of aquatic food	1	
Contamination fraction of plant food	1	
Contamination fraction of meat	1	
Contamination fraction of milk	1	
Livestock fodder intake for meat	27.1	kg/d
Livestock fodder intake for milk	63.25	kg/d
Livestock water intake for meat	50	L/d
Livestock water intake for milk	60	L/d
Growing season for non-leafy vegetables	0.25	y
Growing season for leafy vegetables	0.123	y
Growing season for fodder	0.15	y

Storage time for fruits, non-leafy veg., and grain	14	d
Storage time for leafy vegetables	1	d
Storage time for milk	1	d
Storage time for meat and poultry	20	d
Storage time for livestock fodder	0	d
Fraction of grain in beef cattle feed	0.0743	
Fraction of grain in milk cow feed	0.0308	
Well pumping rate	118	m^3/y
Irrigation rate	0.5	m/y

RESRAD default parameters were used for all other parameters except for the distribution coefficients.

Results from staff's analyses are as follows:

Simulation 1	Simulation 2	Total Dose
151 mrem/yr	**<1 mrem/yr**	**151 mrem/yr**

The dose from the RESRAD analysis is significantly less than the estimate provided by DandD, but still above the 25 mrem/yr dose criterion.

Comparison to II-VI Analysis

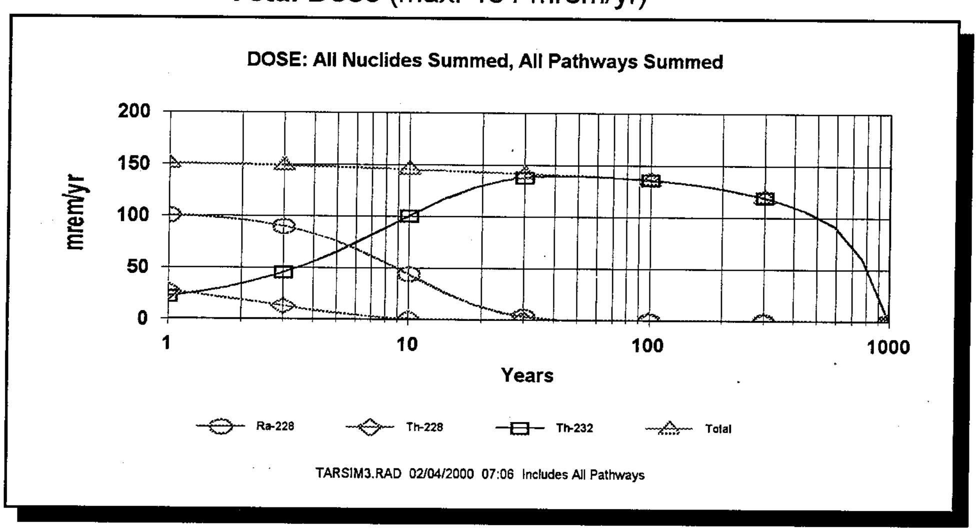
NRC's dual simulation analysis resulted in a dose of 151 mrem/yr to an average member of the critical group. The table below compares NRC's analysis to the analysis conducted by II-VI.

	II-VI	**NRC**	
		Simulation 1	*Simulation 2*
Model			
Software	RESRAD (Ver. 5.60)	RESRAD (Ver. 5.95)	RESRAD (Ver. 5.95)
Scenario	Resident Farmer	Resident Farmer	Resident Farmer
Pathways			
External Gamma	Active	Active	Suppressed
Inhalation (w/o radon)	Active	Active	Suppressed
Plant Ingestion	Active	Active	Active

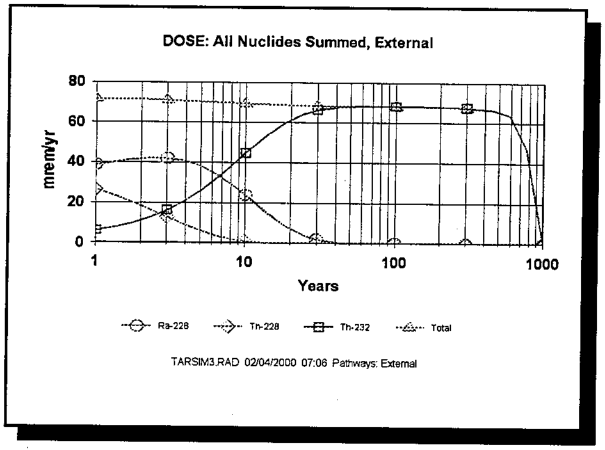
Meat Ingestion	Active	Active	Active
Milk Ingestion	Active	Active	Active
Aquatic Foods	Active	Suppressed	Active
Drinking Water	Active	Suppressed	Active
Soil Ingestion	Active	Active	Suppressed
Radon	Active	Suppressed	Suppressed
Physical Parameters			
Th-232 concentration	1 pCi/g	8.33 pCi/g	25 pCi/g
Area of contamination	1147 m^2	700 m^2	1147 m^2
Thickness of cont.	6 m	0.9 m	6 m
Cap Thickness	2 m	none	2 m
Dose (mrem/yr)			
Water Contribution	5.37 E-10	0.00	6.36 E-19
External Contribution	7.91 E-5	71.8	0.00
Plant (water ind.) Cont.	0.00	67.9	0.00
Total Dose (mrem/yr)	**7.91 E-5**	**151**	**1.02 E-18**
Calculated Disposal Limit			
Equates to 25 mrem	**315,000 pCi/g**	**4.1 pCi/g**	

The three graphs below display the dose from Simulation 1, which essentially accounts for the entire dose. As the above table and the below figures demonstrate, the external and plant (water independent) pathways, account for the overwhelming majority of the dose.

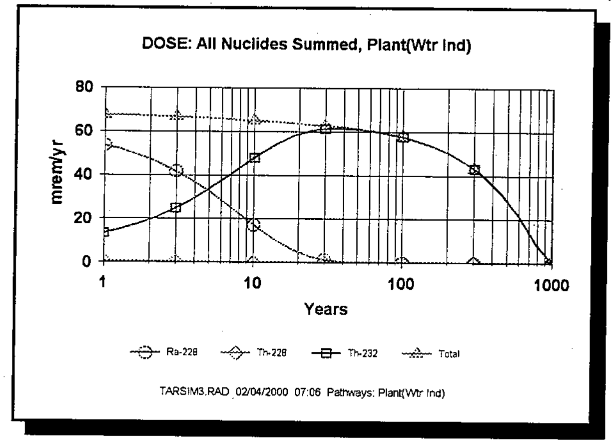
Total Dose (max. 151 mrem/yr)



External Dose (max. 71.8)



Plant (Water Independent) Dose (max. 67.9)



The contrast from staff's Simulation 1 and the low dose achieved in II-VI's model can be accounted for by II-VI's lack of consideration of exhumed radioactive material. The overwhelming majority of the dose came from Scenario I, which placed contaminated material at the surface; a significant aspect of the resident farmer scenario omitted by II-VI.

ALTERNATIVES TO MEET THE DOSE CRITERION

Staff explored ways in which II-VI could dispose of their contaminated material in a municipal landfill. Four "models", which may allow this disposal are discussed below.

Generic Model

The above discussion, tables, and figures detail the generic modeling performed by staff to determine the dose resulting from a proposed disposal of 25 pCi/g each of Thorium-232 and it's progeny. Staff also determined through this generic modeling that 4.1 pCi/g each of Thorium-232 and its progeny is the maximum disposal limit that would result in a dose less than 25 mrem/yr to an average member of the critical group. Therefore, without further modeling or disposal restrictions staff finds that disposal of Thorium-232 and it's progeny at a concentration of 4.1 pCi/g would be protective of the public's health and safety.

Site-Specific Model

The modeling performed by staff and II-VI represents generic and therefore possibly overly conservative parameters for the actual landfill,that II-VI would utilize in Pennsylvania. A more accurate site-specific model could be developed for the landfill using, for example, regional meteorological and subsurface data.

While a site-specific model could result in a slightly lower dose, it is staff's opinion that further analyses would still likely not allow the proposed disposal to meet the 25 mrem/yr criterion.

Doses in excess of the 25 mrem/yr would still be expected due to the significant contribution to the dose from simple external exposure, and also the minor affect expected from inputting the "non-extreme" climatic parameters of Pennsylvania.

Alternate Scenario Model

Changing the scenario, specifically excluding the exhumation of radiological material, could allow the 25 mrem/yr. criterion to be met. This would in effect eliminate the exposure and water independent plant pathways, which are demonstrably the largest contributors to the dose (see abobe). However, alteration of the scenario to exclude exhumation would require the licensee providing information on the restrictions (e.g. deed restrictions) in place at the landfill, which would prohibit future land users from excavating soil for 1,000 years. It is unlikely that such restrictions are in place.

Restricted Disposal Distribution Model

Another way of limiting the dose would be to limit the amount of material (i.e. number of waste packages), which could be exhumed as part of the 600 m^3 foundation of the hypothetical resident farmer's house. The resident farmer scenario assumes a volume of 600 m^3 (200 m^2 area x 3 m depth) is excavated for the foundation. With a 2 m cap this equals 400 m^3 (200 m^2 area x 2 m depth) of clean overburden soil and 200 m^3 (200 m^2 area x1 m depth) of contaminated soil. Up to now we have conservatively assumed that any material excavated below the 2 meter cap would be continuously contaminated with a concentration of 25 pCi/g. If we instead assumed that for example only half of the area below 2 meters was contaminated, the average concentration of the material exhumed from the contaminated zone would be 12.5 pCi/g, effectively cutting the dose from simulation 1 [external and plant (water independent) pathways] in half. However, rather than randomly assigning a contamination distribution staff looked at the specific geometry of II-VI's waste packages and the possible placement of these packages.

The dimensions of II-VI's waste packages are 1.7 x 2.1 x 6.7 meters. If these packages were placed in a layer so that the exposed dimensions of each the package in the foundation area was 1x1.1x6.7 meters, 14.2 "effective" packages could reside in the contaminated 200 m^3 of soil. 14.2 therefore represents the least number of packages which could completely fill the contaminated volume. Stated otherwise, 200m^3 is the most material that could be exhumed by the residential farmer if 14.2 packages lay below the site of the house.

If 14.2 packages lay in the contaminated zone of the foundation, this area would be entirely contaminated and therefore a concentration of 4.1 pCi/g would equate to a dose of 25mrem/yr to an average member of the critical group. The table below demonstrates the maximum concentration in waste packages that equates to a dose of 25 mrem/yr with varying numbers of packages within the exhumed foundation volume. Decreasing the number of packages in the exhumed volume to less than three allows the requested 25 pCi/g disposal limit to meet the 25 mrem/yr dose criterion.

Number of Packages* per exhumation volume**	Concentration equal to 25 mrem/yr
No restriction (max=14.2)	**4.1 pCi/g**
14	**4.2 pCi/g**
13	**4.5 pCi/g**
12	**4.9 PCi/g**
11	**5.3 pCi/g**
10	**5.9 pCi/g**
9	**6.5 pCi/g**
8	**7.3 pCi/g**
7	**8.4 pCi/g**
6	**9.8 pCi/g**
5	**11.7 pCi/g**
4	**14.7 pCi/g**
3	**19.6 pCi/g**
2	**29.4 pCi/g**
1	**58.8 pCi/g**

*Package- 1 x 2.1 x 6.7 meter "effective" packages as defined in text
*Exhumation Volume- volume of contaminated material excavated by resident farmer, equal to 1/3 volume of 600m^3 foundation (or 200m^2 x 1m)

CONCLUSION

II-VI's analysis, which selected the resident farmer scenario, did not adequately account for the dose to an average member of the critical group. Using generic parameters NRC staff found that a disposal limit of 4 pCi/g would meet the 25 mrem/yr dose criterion for a capped disposal at an industrial landfill. However, if the ultimate distribution of waste packages in the landfill were restricted, so that no more than 2 packages could be within the same 200m^2 x 1m volume, the licensee could dispose of material with concentrations up to 25 pCi/g.