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IN REPLY
 REFER TO

JUL 19 2006

DNSC-E

U.S. Nuclear Regulatory Commission
 Region 1, Nuclear Materials Safety Branch
 Division of Nuclear Materials Safety
 ATTN: Ms Betsy Ullrich
 475 Allendale Road
 King of Prussia, PA 19406-1415

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 MS-16

RECEIVED
 REGION 1
 2006 JUL 24 PM 2:45

Re: License STC-133 04000341

**SUBJECT: RESPONSE TO NRC COMMENTS ON DNSC/DLA DOCUMENT
 "PRELIMINARY SITE-SPECIFIC DERIVED CONCENTRATION
 GUIDELINE LEVELS FOR THE HAMMOND DEPOT, HAMMOND,
 INDIANA", CONTROL NO. 138087**

Dear Ms. Ullrich:

Thank you for your letter of June 8, 2006 requesting additional information from the DNSC/DLA regarding the subject document. This letter provides our response to each of the NRC's six comments on the Hammond site. To aid your evaluation, we have repeated each NRC Comment by number and content along with your agency's expected or suggested action of us.

The net result of incorporating the NRC comments is that the proposed soil DCGL values change from 3.4 pCi/g to 2.9 pCi/g for Th-232, and from 2.8 pCi/g to 2.5 pCi/g for U-238. There is effectively no change to the proposed building surface DCGL values.

DNSC requests a conference call with the NRC to discuss these comment responses as soon as possible. We would greatly appreciate NRC concurrence and notification that the DCGL review for the Hammond Depot site will resume quickly. This would assist us with our current project decommissioning and remediation schedule.

Sincerely,

A handwritten signature in black ink, appearing to read "F. Kevin Reilly", written over a printed name.

F. Kevin Reilly
Director, Directorate of Environmental
Management and Safety

Attachment

**RESPONSE TO NRC COMMENTS ON DNSC/DLA DOCUMENT
“PRELIMINARY SITE-SPECIFIC DERIVED CONCENTRATION GUIDELINE
LEVELS FOR THE HAMMOND DEPOT, HAMMOND, INDIANA”,
CONTROL NO. 138087
July 13, 2006**

In reply to the NRC's June 8, 2006 review of the document "Preliminary Site-Specific Derived Concentration Guideline Levels for the Hammond Depot, Hammond, Indiana", the DNSC/DLA provides the following responses. To assist the NRC, each of the agency's comments is repeated as originally provided to the DNSC along with the NRC's suggested action to satisfy that comment. Please note that both condensed and expanded (Enclosure 1) responses to Comment No. 4 are provided.

1. **Comment:** The assumption that residual radioactivity in soil at the Hammond Depot is limited to the top 15 centimeters requires additional justification.

Action: Provide additional information to justify the assumption that contamination is limited to surface soils or provide additional information regarding the intended approach for addressing subsurface contamination.

DNSC Response: The Hammond Site is a surface contaminated site and accordingly, any residual contamination is limited to surface soils. This is based on several supporting factors, including existing process and historical knowledge of the Hammond site. This knowledge base documents the absence of underground tanks, spills, or other release mechanisms that would generate subsurface contamination.

A partial basis for the NRC comment/concern regarding the 15 cm assumption was data from the 2005 ORISE scoping survey that indicated a potential for subsurface contamination. Since the submittal of the dose modeling report for the Hammond Depot, information and data from the ORISE characterization survey (conducted in April and June 2006) is now available which extends DNSC's knowledge of site conditions beyond that gathered during the ORISE scoping survey. Data from the characterization survey supports the classification as a surface contaminated site.

The characterization survey revealed that the estimated total area of onsite contamination is approximately 2700 m², consisting primarily of the Burn Cage/rubble pile area and a larger contiguous area directly southwest of the Burn Cage/rubble pile area. There were also five additional isolated/small areas of contamination identified in the western area of the site. The depth of contamination in the Burn Cage/rubble pile and contiguous area averages 30 cm in depth, ranging from 2 to 40 cm. The characterization survey also identified that the observed depth to slag is nominally 15 to 30 cm, and in a very few cases up to a maximum depth of 45 cm. (Characterization survey findings will be provided to the NRC in support of these statements.)

All contaminated areas have been targeted for remediation to the established site-specific DCGLs by means of soil removal down to the depth of the slag.

Excluding these specific areas known to be contaminated and targeted for remediation, the remaining 99% of the site showed little or no contamination, and all findings were consistent with classification as a surface contaminated site.

In summary, the Hammond site is a surface contaminated site. This classification is based on historical site and process knowledge, and field data from the ORISE characterization survey. The vast majority of the site (99%) has no residual radiological contamination based on the conduct of radiological surveys, sampling, and subsequent laboratory evaluations. Where subsurface contamination does exist (e.g., the Burn Cage area), it does not extend beyond the surface soil/slag interface. Remediation efforts will be conducted as necessary to meet the approved DCGLs for the Hammond site.

2. **Comment:** Sufficient justification for the external gamma shielding factor used in RESRAD is lacking.

Action: Perform additional research, modeling, and/or field experiments to justify the selection of the external gamma shielding factor used in RESRAD for the constituents and building materials present at the Hammond Depot site. Provide the results for review.

DNCS Response: Additional justification for the selected value (0.55) is available in NUREG/CR-5512, Volume 3, pages 6-22 to 6-26. These pages detail the use of Microshield to estimate shielding factors for several building construction scenarios. For the scenario of a 3.5" concrete slab foundation, noted as the minimum thickness allowed by the uniform building code, the estimated shielding factor over a wide range of photon energies is consistently below 0.55 (Page 6-24, Table 6.16). Based on this information in the NUREG document, DNCS believes that continued use of the selected value of 0.55 is justified. Moreover, while this factor is not as conservative as the default value in RESRAD of 0.7, it is considerably more conservative than lower values from the NUREG that would have been more specific to the anticipated building scenario. Lastly, selection of this shielding factor follows NRC preference for consistency with NUREG/CR-5512 as noted in Comments No. 3 and No. 6. *Therefore, the DNCS requests the NRC authorize continued use of the shielding factor (0.55) as provided in the dose modeling report.* There is no known information that would result in a more complete mathematical description of the site.

3. **Comment:** The indoor fraction used in the RESRAD is not consistent with the outdoor fraction selected based on NUREG/CR-5512, Volume 3.

Action: Confirm that you will use an indoor fraction of 0.66.

DNCS Response: The NRC recommended value of 0.66 (actually 0.6571) , was verified from NUREG/CR-5512, Volume 3. The RESRAD code was then re-run with the indoor fraction (IF) set at the NUREG value (0.6571). The results are shown in Table 1 below and indicate that use of the NUREG/CR-5512 value, rather than the default RESRAD value of 0.5, when introduced into RESRAD with no other changes, reduces the DCGL by 15 percent for the thorium-232 decay chain, and by 11 percent for the uranium-238 decay chain.

Table 1: Modified DCGL values for Indoor Fraction (I.F.) at 0.6571

| Decay chain | Proposed DCGL (pCi/g) (IF at 0.5) | Modified DCGL (pCi/g) (IF at 0.6571) |
|-------------|--------------------------------------|---|
| Th-232 | 3.4 | 2.9 (-15%) |
| U-238 | 2.8 | 2.5 (-11%) |

Based on the results of additional RESRAD modeling, the DNCS believes it can adequately implement the reduced DCGLs of 2.9 (Th-232) and 2.5 (U-238) during remediation activities. *Therefore, an indoor fraction of 0.66 will be used. The DNCS concurs that consistency in the selection of indoor/outdoor fractions should be maintained.* The outdoor fraction of 0.12, consistent with the NUREG, remains as cited in the report.

4. **Comment:** Additional justification for the distribution coefficients used in the RESRAD analysis is needed.

Action: Provide documentation that shows how you will reduce the uncertainty, or at a minimum consider and manage the uncertainty in the DCGL calculation, due to the variability of the distribution coefficients and plant transfer factors used in the analysis.

DNCS Response:

Please refer to Enclosure 1 for a detailed response describing the justification for the selection of the distribution coefficients used in the analysis. A summarized response is provided here.

Upon completing the technical assessments directed by the comment, DNCS changed the K_d values chosen for the thorium and uranium contaminants for this site to be appropriate and conservative. Variability in the selected values has been evaluated.

The thorium K_d (Th- K_d) value originally used in the dose modeling report (3200 ml/g) was approximately a factor of 20 less than the RESRAD default of 60,000 ml/g to incorporate a general level of mathematical conservatism into the dose modeling effort. This value was reduced to 100 ml/g to specifically tie it to the following reference: United States Environmental Protection Agency, August

1999, Understanding Variation in Partition Coefficient, K_d , Values; Volume II: Review of Geochemistry and Available K_d Values for Cadmium, Cesium, Chromium, Lead, Plutonium, Radon, Strontium, Thorium, Tritium (^3H), and Uranium, Office of Air and Radiation, EPA 402-R-99-004B, Table I.6 (“Data set containing thorium K_d values”), page I.9. This basis is associated with an environment approximately equivalent to a pH of 9, for a solid matrix (defined as a combination of silt, quartz, organic matter, and calcite (Schist soil)).

The uranium K_d (U- K_d) value originally used in the dose modeling report (35 ml/g) was tied to sandy soils. This value was increased to 100 ml/g to tie directly to the EPA reference, Figure J.4 (“Uranium K_d values used for development of K_d look-up table”), page J.19, at a pH of 9. The DNSC believes the U- K_d of 100 ml/g as the RESRAD input parameter has improved traceability to site-specific conditions.

A full evaluation of K_d values, with regard to the unique properties of the Hammond Depot site, was conducted by the Oak Ridge National Laboratory and is provided in Enclosure 1.

This analysis included an extensive review of appropriate literature/references and an evaluation of the geophysical and chemical properties of the contaminants and the site. This study takes into account the unique properties of the slag, the elevated pH environment (pH of approximately 9), the chemical properties of the contaminants, and the combined effect on contaminant solubility and sorption. This evaluation concludes that the new K_d values suggested for thorium and uranium are more appropriate.

Additional RESRAD calculations performed in response to the NRC inquiry demonstrate that, with regard to the thorium contaminant, variation in the K_d value has no measurable effect on the DCGL for K_d values ranging from the selected value of 3200 ml/g to as low as 100 ml/g. A RESRAD evaluation for the proposed change in the uranium K_d also showed no effect on the DCGL.

Based on the information presented in this response, the DNSC believes that the K_d values for thorium and uranium of 100 ml/g and 100 ml/g, respectively, are conservatively chosen and most appropriate for the Hammond Depot remediation effort. *Therefore, the DNSC requests the NRC authorize use of these revised coefficients for generation of the final dose modeling report.*

5. **Comment:** DLA/DNSC should examine the significance of parameter values related to the plant ingestion pathway.

Action: Determine the significance of parameters affecting the plant ingestion pathway through additional sensitivity and uncertainty analysis, consistent with your finding with respect to Item No. 1 above.

DNSC Response: During the preparation of the dose modeling report, the conceptual site model for the Hammond Depot (Figure 8, page 24) identified the influence of the direct exposure pathway and the corresponding lack of impact of the plant ingestion pathway. This was later expressed in Section 4.3.2.1 (page 32) of the report which described the significance of the ingestion pathways based on conducted sensitivity analyses as “minimal”.

The DNSC response to NRC Comment No. 1 acknowledges recently acquired characterization information that contamination extends beyond a depth of 15 cm (but no greater than 45 cm) at specified, limited, onsite locations. The ORISE characterization survey (June 2006) and follow-on laboratory evaluations demonstrate that contamination does not exist over a vast majority (99%) of the site. Where it is present, e.g. the Burn Cage and immediate surrounding areas, the areas may be remediated by DNSC to the soil/slag interface which extends to a maximum depth of 45 cm. The remediation effort will be focused on meeting the site approved DCGLs. Contamination does not extend beyond this interface.

Based on site characteristics, the overriding predominance of the external gamma radiation exposure pathway (Section 4.3.2.1, page 32 of the dose modeling report), and the remediation that will be conducted down to the depth of the slag as needed to meet the DCGLs, the DNSC does not believe there is a justifiable need to conduct additional sensitivity and uncertainty analysis as it impacts the plant ingestion pathway.

6. **Comment:** DLA/DNCS did not provide sufficient justification for use of the default inhalation rate for the RESRAD-BUILD DCGL calculations.

Action: Justify your use of the default value for the inhalation rate in RESRAD BUILD, or modify your selection of the inhalation rate in RESRAD BUILD.

DNSC Response: As noted in the basis for the NRC comment, a breathing rate of $33.6 \text{ m}^3/\text{day}$ is consistent with NUREG/CR-5512, Volume 3. DNCS acknowledges this value provides a realistically conservative upper bound for the breathing rate. *The parameter value of $33.6 \text{ m}^3/\text{day}$ has been incorporated into the RESRAD-BUILD calculations.*

In line with adopting this parameter value from NUREG/CR-5512, DNCS will also revise the indoor fraction to be consistent with the NUREG. The dose modeling report was based on an overly-conservative indoor fraction of 0.5. NUREG/CR-5512, Volume 3, page 5-6 suggests a more realistic value based on a 45-hour work week for non-agricultural industries. This equates to 97.5 effective 24-hour days, yielding an indoor fraction of 0.267 ($97.5/365$). RESRAD-BUILD was re-run with the inhalation rate selected at $33.6 \text{ m}^3/\text{day}$, and the indoor fraction set to 0.267. The results are shown in Table 2 below and indicate that use of the NUREG values very slightly increases the DCGL for both the thorium-232 decay chain and the uranium-238 decay chain. Based on the

rounded DCGL values of 400 and 800 dpm/100 cm² in the dose modeling report, the revised parameter values result in effectively no change from the originally proposed DCGLs.

Table 2: Modified DCGL values for Inhalation Rate at 33.6 m³/day

| Decay chain | Proposed DCGL (dpm/100 cm ²) (Inhalation Rate at 18 m ³ /day, Indoor Fraction at 0.5) | Modified DCGL (dpm/100 cm ²) (Inhalation Rate at 33.6 m ³ /day, Indoor Fraction at 0.267) |
|-------------|---|---|
| Th-232 | 383* | 405 (+ 6%) |
| U-238 | 761* | 797 (+ 5%) |

* Note that the values in the January 2006 dose modeling report were rounded to 400 and 800 dpm/100 cm², respectively.

ENCLOSURE 1

DNSC FULL RESPONSE TO NRC COMMENT 4 Hammond DCGL Technical Basis (Prepared by Oak Ridge National Laboratory)

Literature for estimating appropriate and technically defensible Hammond site-specific uranium and thorium K_d s at elevated pH levels in ground water were reviewed.

The uranium source term at the site is very low from a historical perspective and all source materials were contained in drums/closed boxes and stored in buildings. Any soil contamination is from thorium and may require removal for disposal. Based on sampling and inductively-coupled plasma mass spectroscopic analyses, the uranium content of the thorium nitrate inventory (863,678 kg in 2,309 drums) stored at Hammond Depot in 1999 was determined to be only 418 grams or 0.48 ppm. The thorium and uranium-containing ore was processed chemically prior to being delivered to the government stockpile. Hence, the natural uranium concentration present in the thorium nitrate source material was very low and not in secular equilibrium with its progeny. The thorium nitrate stockpile source term has been removed from the depot. If even percent quantities of the thorium inventory were dispersed from repackaging operations, the uranium source term would be indistinguishable from background. The columbium/tantalum minerals stored at Hammond Depot in 1999 (149,302 kg) contained uranium and thorium. All the minerals were stored in packages and kept indoors. The estimated total uranium in the columbium/tantalum minerals was about 212 kg. The source term consisting of the columbium/tantalum minerals has been removed from the depot. It should also be pointed out that these minerals would be relatively insoluble in ground water.

The subsurface slag at the Hammond Depot was a molten/poured produced slag which was vitrified by rapid cooling. In the ground over time, enough $\text{Ca}(\text{OH})_2$ has leached out causing the pH of the ground water to increase. The Calumet aquifer underlies the Hammond Depot and a section of the aquifer was characterized by the U.S. Geological Survey, with analytical data used herein. The pH values obtained in water from 21 slag-contact well samples ranged from 6.6 to 12.3 with a median of 8.7 (approximately equivalent to 9) compared with pH values of 6 to 7.7 for background.⁽²⁾ Water from slag-affected wells contained pH levels ranging from 6.9 to 9.9.⁽²⁾ Results of analyses of ground water and surface water from Bairstow Landfill near Hammond, Indiana (August 1996) found uranium concentrations below the detection levels of 1 and 2 $\mu\text{g}/\text{L}$ (Table 2, page 44). Interestingly, the uranium concentration was below the detection limit regardless of the alkalinity or pH.⁽²⁾ Analyses were also made of solid-phase samples from the Bairstow Landfill site (Table 3 pages 46–50).⁽²⁾ Twelve of the 16 samples analyzed were below the detection limit of 10 ppm for uranium. The concentration of uranium for the other four samples ranged from 10 to 19 ppm. All were very low. The aluminum, iron, and titanium percentages in the samples were fairly high, ranging from 2 to 10 for aluminum, 1.3 to 11.4 for iron, and 0.11 to 0.45 for titanium. The percentages for calcium and potassium were (0.75 to 22) and (0.21 to 3.6), respectively. All these elements have the potential of minimizing uranium solubility.

The vadose zone at the Hammond depot site includes the top soil and Hammond slag layer. The topsoil is a sandy-loam soil and varies in depth from a few inches to a few feet. The slag layer underneath the topsoil varies in depth from 2-4 meters (minimum), as depicted in Figure 1.

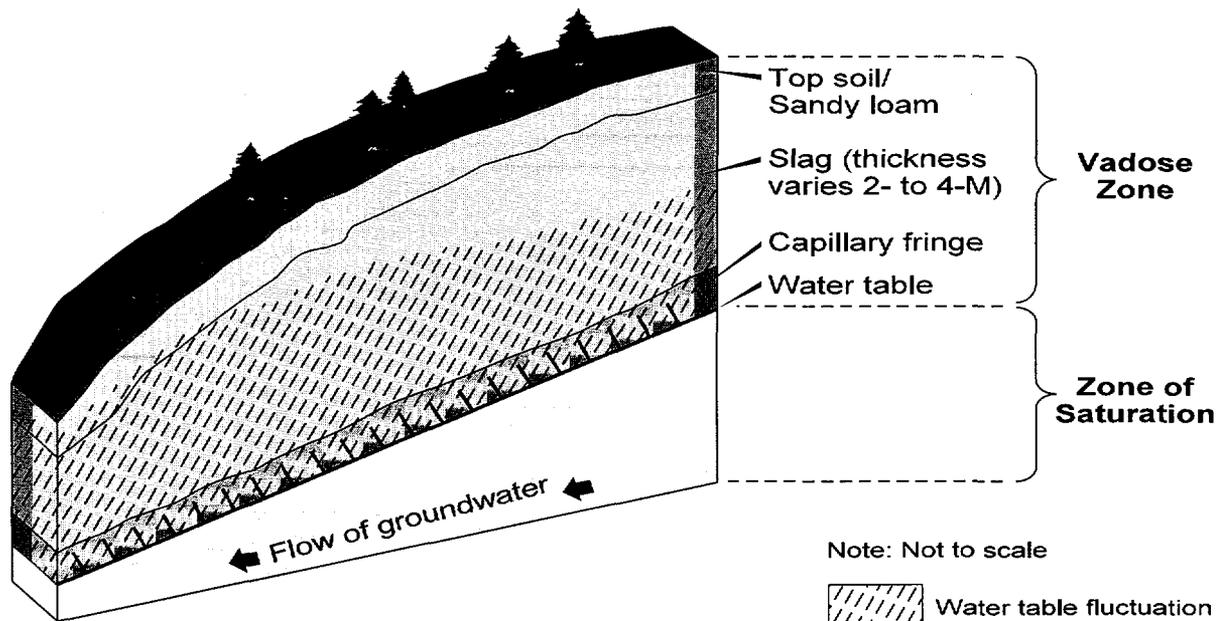
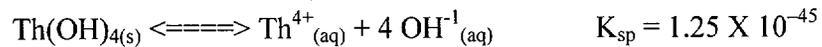


Figure 1: Simple Graphic Depicting Hammond Site Generic Groundwater Flow

Thorium K_d Technical Basis

The RESRAD calculations were re-evaluated with the thorium K_d input value reduced from 3,200 ml/g to 100 ml/g. This change adds conservatism and ties the K_d directly to Table I.6, page I.9 (“Data set containing thorium K_d values”), of the following EPA reference: United States Environmental Protection Agency, August 1999, Understanding Variation in Partition Coefficient, K_d , Values; Volume II: Review of Geochemistry and Available K_d Values for Cadmium, Cesium, Chromium, Lead, Plutonium, Radon, Strontium, Thorium, Tritium (^3H), and Uranium, Office of Air and Radiation, EPA 402-R-99-004B.⁽³⁾ This basis is associated with an environment approximately equivalent to a pH of 9, for a solid matrix (defined as a combination of silt, quartz, organic matter, and calcite (Schist soil)). The DCGL was not impacted by this change. Further discussion of the slag chemistry and solubility and pH basis is provided in the U- K_d discussion below.

It is noteworthy that thorium precipitates when it comes in contact with a solution at high pH. The solubility products for $\text{Ca}(\text{OH})_2$ and $\text{Th}(\text{OH})_4$ are found below, with equilibrium constants shown⁽⁴⁾



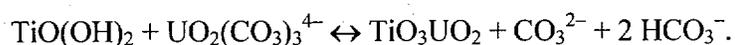
Uranium K_d Technical Basis

Based on the technical studies/assessments described herein, the DNSC requests modifying the U- K_d to 100 ml/g to tie directly to the EPA reference⁽³⁾, Figure J.4, page J.19, at a pH of 9. The DNSC believes using the U- K_d of 100 ml/g as the RESRAD input parameter will improve traceability to site-specific conditions.

Sandy-soil constitutes a range of varying silt and clay fractions. The quartz sand has very little ion exchange capacity by itself and weak affinity for adsorption of ionic species, with uranium K_d values approaching unity for certain conditions. K_d s depend on the soil sample and the experimental set up. The measurements are only comparable if the same solid surface area to solution volume is used. Alumina/silica secondary mineral coatings and hematite (iron oxide) coatings can contribute to sandy soil adsorption intensities and exchange capacities, as evidenced by the research completed for co-precipitation (and immobilization) of radionuclides in Portland cement. Ground granulated blast furnace slag (GGBFS) has been used for many years as a supplementary cementitious material in Portland cement concrete, either as a mineral admixture or as a component of blended cement.

The following statement made in Chapter 32 (page 105) of the Argonne National Laboratory Data Collection Handbook is noteworthy: "Because of its dependence on many soil properties, the value of the distribution coefficient for a specific radionuclide in soils can range over several orders of magnitude under different conditions."⁽⁵⁾ In Appendix I of the EPA Report 402-R-99-004B, the authors indicate that the values provided are based on assumptions that are not appropriate for systems containing high alkalinity (second paragraph of page I.2). The default coefficient is specified for groundwater conditions that are found in normal remediation sites with the pH usually ranging from 6 to 8, which is probably appropriate for transport by rainwater through on-site soil and the soil/slag interface. In the case of the previous wetlands around Hammond that have been stabilized with slag⁽²⁾⁽⁶⁾, the system contains high alkalinity elements. A system more appropriate for comparison with the Hammond site is one made up of cementitious materials, including iron. Water associated with the subsurface slag tend to become alkaline because of leached $\text{Ca}(\text{OH})_2$. The chemistry is well documented by the scientists who are working to isolate radiological wastes. Direct correlation with sand alone cannot be made between pH and the various species of uranium (phosphates, carbonates, fluoride, and hydroxide). Certain compounds in cement and iron compounds have good ion exchange properties and can limit the uranium solubility in groundwater or increase uranium K_d . Titanium has also been

identified as one of the constituents of the slag. Hydrous titanium oxide is the best known sorbent that has been found to be effective in removing uranium from sea water.⁽⁷⁾⁽⁸⁾ The concentration of uranium in sea water is ~3.3 ppb and the uranium is present as the $\text{UO}_2(\text{CO}_3)_3^{2-}$. The pH of sea water is about 8.1. Hydrous titanium oxide in combination with hydrous iron oxide has also been proven to be effective. Uranium sorption involves release of carbonate-bicarbonate ions.⁽⁸⁾ The mechanism can be represented by the following equation:



The hydrous metal oxides help to minimize the solubility of uranium and help to provide higher K_{ds} .

The mean K_d value of 35 ml/g which was used as the input in the RESRAD model to calculate the corresponding natural uranium DCGL is associated with sandy soil, and was extracted from table J.3, page J.18, of the EPA reference. We believe that 35ml/g is actually an overly conservative K_d considering the fact that the cementitious slag layer contains high percentages of uranium sorbents titanium, iron and aluminum which enhance the 'sandy soil' basis for reducing uranium solubility/mobility and transport to the ground water. Figure J.4 provides the K_d values for each soil type and associated range of K_d values listed for uranium. The K_d batch tests, conducted with ferrihydrite as a function of pH, gave some of the highest K_d values. At pHs of 7, 8 and 9, the K_d values were about 400,000, 300,000, and 100 ml/g respectively. The solubility of any available trace, natural uranium species in the groundwater is reduced because co-precipitation of uranium compounds occurs with the calcium silicate minerals and iron compounds in the slag. The high calcium silicate mineral and iron content in the 2-4 meter (and greater) thick slag layer encompassing the Hammond Depot acts as a barrier/buffer to the transport of uranium to the ground water. The new RESRAD U- K_d input parameter of 100 ml/g ties directly to Figure J.4 at a pH approximately equivalent to 9.

The following experimental examples demonstrate the potential impact of certain materials in limiting the solubility of uranium in ground water. Drum-scale (30 gal) batch and sequential contact leaching tests were conducted at ORNL to study the solubilization of uranium in synthetic groundwater and landfill water (TCLP) from five different uranium contaminated waste types that are generated in the production operations at the Oak Ridge Y-12 plant.⁽⁹⁾ The groundwater was a simulated Conasauga Formation Saprolite water which had a pH of 7.3 and a low concentration of Na^+ , Cl^- and HCO_3^- . The synthetic landfill leachant was prepared by the TCLP method which was a 0.1 M sodium acetate-acetic acid buffer solution with a pH of 4.9. A key find was that uranium was extremely resistant to being leached in waste type that contained iron metal and aluminum machine shop turnings. In some cases, the uranium concentration of the leachant would increase the first day and subsequently decrease. The decrease in uranium was probably caused by the sorption of the soluble uranium by the gelatinous hydrous iron oxide sludge that was formed from the iron turnings. Hydrous iron oxide is an excellent inorganic ion exchange material. Tests were also conducted in which iron turnings were added to leaches containing known amounts of soluble uranium (see

Fig. 2). These test confirmed the limiting and controlling effect of iron turnings on uranium solubility; in each test the uranium decreased rapidly.

ORNL DWG 90A-782

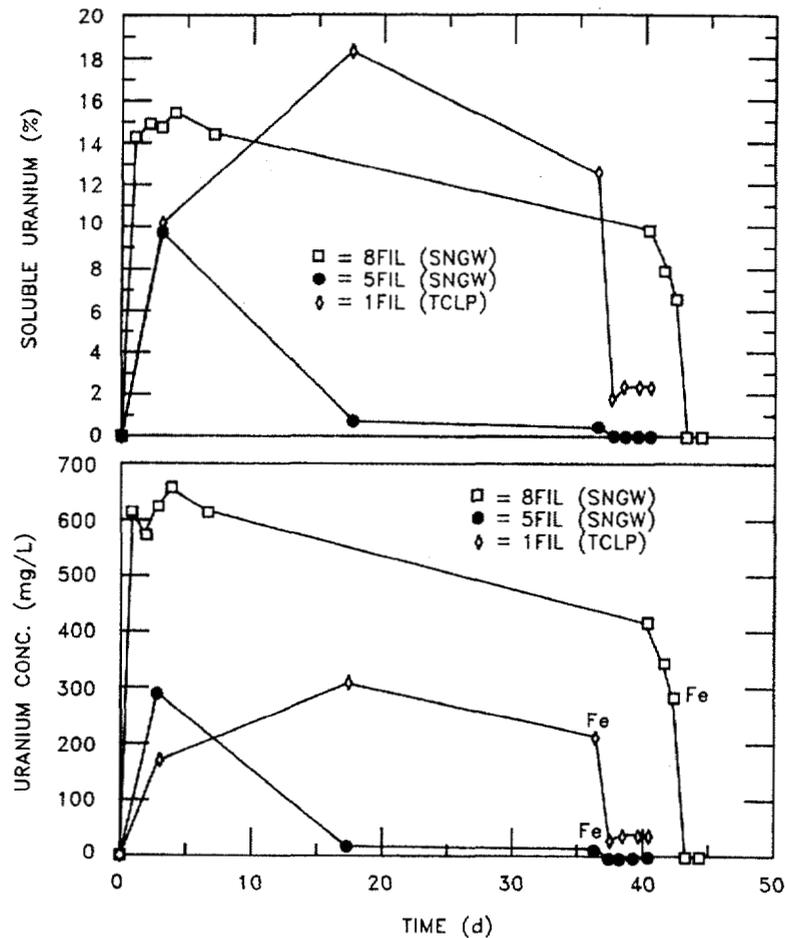


Figure 2 Effect of adding iron turning to leachates containing soluble uranium.

There is also clear evidence that uranyl-silicates control the solubility of uranium. In a study⁽¹⁰⁾ by D.C. Pryke et al, the concentration of U in equilibrium with bentonite (semectitic clay) was 6×10^{-4} M. When blast furnace slag was added⁽¹⁰⁾ to the mixture, the U concentration dropped to 1×10^{-7} M. After aging, the U concentrations dropped to 7×10^{-10} M with the formations of becquerelite⁽¹¹⁾, calcium uranyl oxide, and uranophane⁽¹²⁾. Therefore, the presence of blast furnace slag at this site will significantly retard the migration of available trace uranium into the ground water.

Research by Enzo Curti (page 78, table 7-3)⁽¹³⁾ shows the uranium distribution coefficients for sorption on cement phases ranges from 100 to 5,000 ml/g. The experimental work by H. S. Syed⁽¹⁴⁾ provided an analytical expression for uranium K_d approximation at different solution compositions on soil sediments for a normal pH range of 6-8. The calculation required calcium and magnesium concentration data, which was

extracted at the minimum concentrations identified in the characterization studies at the slag/ground water interface published in references 2 and 5. The lowest calculated result for the uranium partitioning per use of these references was 1,320 ml/g, albeit this reference was for a pH range from 6–8. The result is given because there is no doubt surface transfer environs within this pH range are applicable within the site, especially at the soil/slag interface, and the fact the median value for all samples in the USGS reference was 8.7 (approximately equivalent to 9).

L. P. Moroni and F. P Glasser evaluated the uranium solubility with cement components at high pH. Under conditions given in Table 4, page 247, the uranium solubilities decline to $10^{-8} - 10^{-9}$ mol/L⁽¹⁵⁾. Therefore, high silica cements such as blast furnace slags reduce the mobility of uranium and other radionuclides. Table 1 summarizes insoluble uranium compounds that can potentially form which are thermodynamically favored.

Table 1. Values of $\Delta G_{f,298}^{\circ}$ for the U(VI) minerals

| Uranyl phases | Formula | kJoule/mol ⁽¹⁶⁾ | kJoule/mol ⁽¹⁷⁾ |
|----------------|--|----------------------------|----------------------------|
| Metaschoepite | $[(\text{UO}_2)_8\text{O}_2(\text{OH})_{12}]^*(\text{H}_2\text{O})_{10}$ | -13,092.0 | -13,092.0 |
| Becquerelite | $\text{Ca}[(\text{UO}_2)_6\text{O}_4(\text{OH})_6]^*(\text{H}_2\text{O})_8$ | -10,324.7 | -10,305.8 |
| Rutherfordine | UO_2CO_3 | -1,563.0 | -1,563.0 |
| Uranocalcarite | $\text{Ca}_2[(\text{UO}_2)_3(\text{CO}_3)(\text{OH})_6]^*(\text{H}_2\text{O})_3$ | -6,036.7 | -6,037.0 |
| Sharpite | $\text{Ca}[(\text{UO}_2)_6(\text{CO}_3)_5(\text{OH})_4]^*(\text{H}_2\text{O})_6$ | -11,607.6 | -11,601.1 |
| Fontanite | $\text{Ca}[(\text{UO}_2)_3(\text{CO}_3)_4]^*(\text{H}_2\text{O})_3$ | -6,524.7 | -6,523.1 |
| Liebigite | $\text{Ca}_2[(\text{UO}_2)(\text{CO}_3)_3]^*(\text{H}_2\text{O})_{11}$ | -6,446.4 | -6,468.6 |
| Haiweeite | $\text{Ca}[(\text{UO}_2)_2(\text{Si}_2\text{O}_5)_3]^*(\text{H}_2\text{O})_5$ | -9,367.2 | -9,431.4 |
| Ursilite | $\text{Ca}_4[(\text{UO}_2)_4(\text{Si}_2\text{O}_5)_5(\text{OH})_6]^*(\text{H}_2\text{O})$ | -20,377.4 | -20,504.6 |
| Soddyite | $[(\text{UO}_2)_2\text{SiO}_4]^*(\text{H}_2\text{O})_2$ | -3,653.0 | -3,658.0 |
| Uranophane | $\text{Ca}[(\text{UO}_2)(\text{SiO}_3\text{OH})]_2^*(\text{H}_2\text{O})_5$ | -6,192.3 | -6,210.6 |

Plant Transfer Factors

The historical site assessment for Hammond Depot records releases of thorium nitrate contamination at the former pallet Burn Cage area, but there were no records of releases of materials containing significant quantities of uranium. As noted earlier, the uranium content of the entire thorium nitrate inventory in 1999 (over 863,000 kg in over 2,300 drums) was about 418 grams. The total quantity of thorium released at the former pallet Burn Cage is unknown, but it is likely to be much less than the contents of a single drum (possibly 5-10%). Ten percent of a single drum of thorium nitrate would contain roughly 18 mg of uranium that is not in secular equilibrium with its progeny. When distributed over the volume known to be contaminated with thorium, this quantity of uranium would be indistinguishable from background.

The depth of thorium contamination in the outside sandy topsoil was assessed during detailed characterization. The depth ranges from 2 to 45 cm (depending upon the varying depth of soil above the blast furnace slag) over a contiguous area of approximately 1,970 m² (about ½ acre) in the former pallet Burn Cage area. For the remainder of the site, several other small, localized areas of contamination were also identified with the depth of the contamination extending to the slag interface. There were no other indications of contamination identified over the remaining (99%) of the site area. Blast furnace slag samples taken June 5, 2006 from beneath the topsoil at the former pallet Burn Cage area contained no radioactivity above background. Remediation of the former pallet Burn Cage area will likely result in removal of the sandy topsoil down to the blast furnace slag. Plant growth is restricted to on-site areas with adequate topsoil. The slag layer significantly suppresses the growth of typical food plants. Visible inspection at the Hammond site indicates significantly retarded growth of grass, weeds, brush, etc. In the absence of measurable uranium contamination, the default plant transfer factors are conservative.

Conclusion

From a historical perspective, the uranium source term at the site is very low and all source materials were contained in drums/closed boxes and stored in buildings and have been removed from the site. Presently, any soil contamination at the site should only be from thorium spills and may require removal for disposal. Based on the information presented in this response, we believe that the K_d values for thorium and uranium of 100 ml/g and 100 ml/g, respectively, are appropriate for this site and technically defensible. The uranium K_d of 100 ml/g is tied to published data for sandy-soil in the normal ground water pH range, with some credit for the good uranium retention characteristics of the subsurface slag that is present. Again, given the wide range of K_d s presented in the literature and the specific characteristics of cementitious slag with Fe cations, this value is a very conservative value for the uranium K_d .

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