TECHNICAL MEMORANDUM

To: Mr. Daniel Shrum

From: Janet Schramke, Ph.D.

Subject: Review of Institute for Energy and Environmental Research Report Related to Shallow Land Disposal of Depleted Uranium

Date: November 21, 2007

Introduction

In September 2007, the Utah Division of Radiation Control (DRC) received a public comment from HEAL Utah (Thomas 2007) regarding the proposed renewal of Energy*Solutions*' Radioactive Material License 2300249. This public comment included modifications proposed by HEAL Utah. One of these proposed modifications was:

> Disposal of Depleted Uranium (DU) or Low-Enriched Uranium (LEU) in large amounts, as from enrichment facilities and as recovered from high-level waste reprocessing, should be specifically excluded from the scope of Energy*Solutions*' license.

HEAL Utah supported this proposed modification with a technical report (Makhijani 2007). Statements made by Makhijani (2007) regarding the radiochemical and radiological properties of uranium included:

- DU in its radiochemical and radiological properties is most like Greater-than-Class-C (GTCC) waste with long-lived, alpha-emitting transuranic radionuclides and should be classified as GTCC waste based on its characteristics, longevity, and hazard.

- Radiological analyses show that disposal at shallow land disposal sites would result in doses far above the maximum allowable limits under 10 CFR 61 Subpart C.

- Uranium recovered from reprocessing plants of any kind is more radioactive than DU and should also be classified as GTCC waste.

This technical memorandum examines the evidence and reasoning supporting these assertions by Makhijani (2007).

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Classification of Depleted Uranium Waste

Federal regulations regarding low-level waste disposal are described in 10 CFR 61. Low-level waste is classified as Class A, Class B, Class C, or Greater than Class C waste using nuclide concentrations listed in Tables 1 and 2 of 10 CFR 61.55 (Utah Administrative Code, Section 19-3-102). These tables contain longer-lived radionuclides, such as carbon-14 and technetium-99 (Table 1), as well as short-lived radionuclides, such as tritium and cobalt-60 (Table 2). If radioactive waste does not contain any of the nuclides listed in these tables, it is defined as Class A waste [10 CFR 61.55(a)(6)].

The composition of DU, when compared to Tables 1 and 2 in 10 CFR 61.55, meets the Class A criteria. However, because the rulemaking for 10 CFR 61 did not consider DU waste streams such as those from uranium enrichment facilities, the Nuclear Regulatory Commission (NRC) has directed its staff to consider whether such large quantities of DU warrant amending 10 CFR 61.55(a)(6) or the waste classification tables (NRC 2005). Consequently, the classification of large quantities of DU, such as those derived from a uranium enrichment facility, is unresolved at this time. Classification of smaller amounts of DU, in quantities consistent with the types of waste being disposed at the time of the initial rulemaking, continues to be covered by 10 CFR 61.55.

Radiological and Chemical Properties of Depleted Uranium

The isotopic compositions of DU and natural uranium are compared in Table 1. Because DU contains smaller concentrations of uranium-234 and uranium-235 than natural uranium, its specific activity is only about 60% of the specific activity of natural uranium. Consequently, its radiological hazard is less than that of natural uranium. The radiological hazards of both natural and depleted uranium are low because of their low specific activities; for example, ATSDR (1999) has stated that "because the specific activities of natural and depleted uranium are low, no radiological health hazard is expected from exposure to natural and depleted uranium."

Table 1. Isotopic Compositions of Natural and Depleted Uranium and Isotopic Half-Lives of Uranium Isotopes (WHO 2001, Meinrath et al. 2003)[1]

Isotope	Natural Uranium (%)	DU (%)	Half-life (years)
Uranium-234	0.0054	Approximately 0.001	245,500
Uranium-235	0.72	0.2 to 0.3	704,000,000
Uranium-238	99.27	99.7 to 99.8	4,470,000,000

[1] Schramke (2006) previously provided a technical review of Makhijani and Smith (2004, 2005). Because much of the information in Makhijani (2007) is taken from the previous Makhijani and Smith documents, Tables 1 and 2 and some of the text of the current technical memorandum are reproduced from the earlier review.

Because the chemical hazard of uranium does not depend on its isotopic composition, DU has the same chemical toxicity as natural uranium (WHO 2001). The chemical behavior of DU and natural uranium in the environment is the same. Consequently, performance modeling that has been carried out for disposal of natural uranium at the Energy*Solution*s facility at Clive, Utah is valid for the chemical risk from DU, but would overestimate radiological risk because of the lower specific activity of DU.

Makhijani (2007, Table 1) compared the radiological characteristics of uranium isotopes in DU to those of some transuranic radionuclides; this table is the same as Table 2 in Makhijani and Smith (2004). This information is reproduced in the first four columns of Table 2 below. Based on decay mode and alpha particle energy, the uranium isotopes might appear similar to the transuranic radionuclides. However, because of its longer half life, uranium-238 has a much lower specific activity than the other isotopes in Table 2. Because significant amounts of uranium-234 and uranium-235 are removed from DU during the enrichment process, DU has a lower specific activity than natural uranium and a much lower specific activity than any of the transuranics listed in Table 2. Examination of the specific activities of these materials therefore shows that DU is not similar to the transuranic radionuclides in its radiological characteristics. In fact, DU is most similar to natural uranium, although it has a lower specific activity (Table 2).

Table 2. Radiological Properties of Uranium Isotopes, Selected Transuranic Isotopes, Natural Uranium, and Depleted Uranium (WHO 2001, Meinrath et al. 2003, ANL 2005)

Isotope	Decay Mode	Alpha Particle Energy (MeV)	Half Life (y)	Specific Activity (nCi/g)
Uranium-234	Alpha	4.8	245,500	6,237,000
Uranium-235	Alpha and gamma	4.4	704,000,000	2,160
Uranium-238	Alpha plus spontaneous fission	4.1	4,470,000,000	335
Americium-241	Alpha	5.5	430	3,500,000,000
Neptunium-237	Alpha	4.8	2,100,000	710,000
Plutonium-238	Alpha	5.5	88	17,000,000,000
Plutonium-239	Alpha	5.1	24,000	63,000,000
Plutonium-240	Alpha	5.2	6,500	230,000,000
Natural Uranium (metal)	--	--	--	686
DU (metal)[1]	--	--	--	400
DU (U_3O_8)[1]	--	--	--	339
DU (UO_2)[1]	--	--	--	352

[1] freshly prepared

Shallow Land Disposal

Makhijani (2007) addressed the potential shallow land disposal of large amounts of DU from enrichment plants:

> It should also be noted that quantitative evaluations conducted by the NRC, Sandia National Laboratory, and IEER of shallow land disposal of DU from enrichment plants – that is, for large amounts of DU, carried to the time of peak dose or at least well beyond 1,000 years, have all concluded that such disposal would cause the dose limits of the low-level waste regulation, 10 CFR 61 Subpart C, to be greatly exceeded.

This assertion was supported by a footnote stating that Kozak et al. (1992) provided dose estimates assuming wet climate conditions, whereas Makhijani and Smith (2004) considered dry climate conditions (Makhijani 2007, page 13). On this basis, Makhijani (2007) stated that the "10 CFR 61 standard was exceeded at all shallow land burial sites, regardless of climate." However, neither the analysis by Kozak et al. (1992) nor the calculations of Makhijani and Smith (2004) are applicable to the Energy*Solutions* site because they included assumptions that are inconsistent with site conditions.

Kozak et al. (1992) provided a generic analysis of DU disposal as Class A waste. Schramke (2006) previously summarized the significant differences between the assumed conditions for the Kozak et al. (1992) generic performance assessment and conditions at the Energy*Solutions* disposal site. These differences included the assumption of hydrological characteristics consistent with a humid southeastern U.S. reference site for modeling groundwater transport, such as much higher infiltration rates and groundwater transport velocity than those observed at the Energy*Solutions* site. In addition, the "intruder-construction" and "intruder-resident" scenarios modeled by Kozak et al. (1992) appeared to have included construction of a house at the site that disturbed the waste and exposures to residents of such a house. In the Kozak et al. (1992) analysis, the resident was exposed by pathways considered in the construction scenario, and also consumed food grown in contaminated soil. These scenarios are extremely unlikely at the Energy*Solutions* site because of climate, soil, and groundwater conditions. These site conditions have prevented human habitation in the past and are extremely likely to prevent future habitation. Consequently, the results of the performance assessment by Kozak et al. (1992) are not applicable to the Energy*Solutions* site.

Makhijani and Smith (2004) performed a series of RESRAD (Yu et al. 2001) calculations to estimate radiation doses from shallow land disposal of DU under various assumed conditions. A number of the assumptions used by Makhijani and Smith (2004) in the RESRAD calculations are inconsistent with conditions at the Energy*Solutions*, as previously described by Schramke (2006):

- Resident farmer scenario– this scenario included the assumption that a family lives at the site, drinks the groundwater, and consumes crops irrigated with site groundwater. Because of the high salinity of the groundwater at the Energy*Solutions* site, with total dissolved solids on the order of 50,000 mg/L, the

site groundwater could not be used as a source of drinking water or for irrigation. Soil, climate and groundwater conditions at the site have precluded human habitation in the past and the site is extremely unlikely to be inhabited in the future.

- The calculations did not appear to account for the presence of an engineered cover that would limit erosion and surface exposure of the DU.

- It was assumed that DU would be placed in a monolithic layer. In the unlikely event that the DU was exposed by erosion through the cover, it is doubtful that crops would grow in a soil that consisted only of DU or secondary uranium phases.

- The consideration of dose from radon-222 did not appear to take into account the presence of a radon cover on disposal cells at the Energy*Solutions* facility.

For these reasons, the dose assessment performed by Makhijani and Smith (2004) is not relevant to DU disposal at the Energy*Solutions* site.

Factors at the Energy*Solutions* site that limit the release of uranium to the groundwater and its transport to the point of exposure include disposal cell design, low rainfall and infiltration rates, low groundwater flow rates, and the presence of soil constituents that will remove uranium from leachate and groundwater by sorption. The potential radon-222 dose at the site is limited by the presence of a radon cover, and a cover is placed over the disposal cells to limit erosion. In addition, because of the low precipitation and high groundwater salinity at the site, future human habitation and associated exposure pathways are extremely unlikely.

Site-specific performance modeling for uranium disposal at the Energy*Solutions* site has demonstrated that natural uranium can be safely placed in the disposal cells, even when the waste is assumed to only consist of uranium (Whetstone 2000a, 2000b). These calculations provide an extreme upper limit on the risks of uranium disposal at the Energy*Solutions* site, because uranium makes up only a fraction of the accepted waste. However, even when the disposal cells were assumed to contain 100% natural uranium, risks were found to be within regulatory limits. The chemical risks associated with DU are the same as natural uranium and the radiological risks of DU are significantly smaller. Therefore, the performance assessments carried out with natural uranium demonstrate that DU can be safely placed in the Energy*Solutions* facility.

Makhijani (2007, page 8) states that uranium recovered during reprocessing has an even higher specific activity than DU. Makhijani (2007) then states that, because DU cannot be safely placed in a shallow land disposal facility, any uranium recovered during reprocessing also cannot be safely placed in such a facility. If DU is derived from uranium reprocessing, it is likely to include trace amounts of uranium-236, plutonium, americium, neptunium, and technetium-99 (DOD 2000, IAEA 2003). However, it has been shown that DU derived from reprocessing contains contaminants at the parts per billion level, which cause only a 1% increase in the dose from DU (DOD 2000, IAEA

2003). IAEA (2003) concluded that such a small increase in radiation dose was insignificant with respect to both the chemical and radiological toxicity of DU. Consequently, Makhijani (2007) has not demonstrated that DU recovered during reprocessing cannot be placed in a shallow land disposal facility.

Conclusions

The Makhijani (2007) report contains information that was previously presented by Makhijani and Smith (2004, 2005). Review of the information presented in these reports indicates that the authors did not support their assertions regarding the radiological hazards of DU or the assertion that shallow land disposal of DU at a facility such as the Energy*Solutions* site would cause radiation doses in excess of those established by low-level waste regulations (10 CFR 61 Subpart C). They also did not provide credible evidence that DU should be classified as GTCC waste.

The available information regarding uranium disposal at the Energy*Solutions* site indicates that the site can be safely used for DU disposal. This information includes disposal cell design and site characteristics, as well as the relatively low radiological hazard of depleted uranium. Site-specific performance modeling carried out for the disposal of natural uranium has demonstrated acceptably low chemical and radiological risks. Because of the lower radiological risk from DU, these performance modeling studies demonstrate that DU can also be safely placed in disposal cells at the site.

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