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Army Anagnostopoulos Exh. # 1-C

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U.S. NUCLEAR REGULATORY COMMISSION

In the Matter of US ARMY (JEFFERSON PROVING GROUND)

Docket No. 40-8838-MLA Official Exhibit No. ARMY EXH. # 1-C

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Long-Term Fate of Depleted Uranium at Aberdeen and Yuma Proving Grounds, Phase II: Human Health and Ecological Risk Assessments, LA-13156-MS, LANL National Laboratory, 1996. (Section 3.6.3, page 35)

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C.3

Long-Term Fate of Depleted Uranium at Aberdeen and Yuma Proving Grounds, Phase II: Human Health and Ecological Risk Assessments

Los Alamos
NATIONAL LABORATORY

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Table 3-4. Various statistics from the uncertainty analysis of the steady-state model for predicted values of C_i.

Statistic	Value
Number of Trials	10,000
Mean	2.2×10^{-4} pCi/g
Median	1.7×10^{-4} pCi/g
Mode	1.4×10^{-4} pCi/g
Standard Deviation	2.3×10^{-4} pCi/g
Range Minimum Maximum	 0 pCi/g 5.0×10^{-3} pCi/g
Skewness	6.38

3.6.3. Results and Discussion

Equations 3-16–3-21 were used in Monte Carlo simulations to evaluate the parameters that were most influenced by variations in input values. Monte Carlo simulation was used to evaluate which parameters were the most sensitive. To estimate the sensitivity of the model, the parameters were varied at random within their ranges, just as they were in the uncertainty analysis. However, only one parameter per simulation was varied, and the remaining parameters were held at fixed values. Ten thousand iterations were run, and then the probability distribution was constructed and statistics were determined for each family of C_is. The standard deviation of the estimated C_i was one measure of the variation caused by each parameter. Parameters that resulted in the largest variation in C_i values were considered sensitive parameters.

Each equation describes a particular part of the model and, therefore, each has a set of sensitive parameters. The contribution of some of the sensitive parameters overshadows the effects of others when the whole model is considered, thereby rendering insensitive some parameters that were at one level considered sensitive. One example is the calculation of λ_L, the amount of DU lost through soil leaching, in Equation 3-18. The velocity with which water flows vertically through the soil profile is not known from field measurements. One report (U.S. Army 1990b) states that the velocity of groundwater flow is "several inches per day" and leaves significant uncertainty in the V_w parameter. While the value of λ_L depends on V_w in Equation 3-19, variations of V_w had no significant effect on the calculated value of C_i (Equation 3-16) because other variables were more influential. Distributions for all variables listed in Equations 3-16 through 3-21 were constructed initially, then parameters such as V_w were eliminated to simplify the analyses.

After the parameters that contributed less than 1% to C_i were eliminated, the sensitivity analysis showed that soil concentration (C_s, Equation 3-16), dust mass in the air (imbedded in the calculation of d_2, Equation 3-20), and the weathering half-time (t_w, Equation 3-21) explained about 98% of the variance in the predicted values of C_i. Table 3-5 shows the six most influential parameters in the model in terms of the percent to which they contribute to the variance in C_i.

Table 3-4 shows that the distribution of values of C_i is positively skewed and indicates that the probability of a value less than the mean is much greater than the probability of a value greater than the mean. The median value of C_i in Table 3-4 shows that there are equal numbers of occurrences above and below 1.7×10^{-4} pCi/g, and the mode shows that the most probable estimate of C_i is about 1.4×10^{-4} pCi/g. The standard deviation of the mean is slightly larger than the mean (about 2.3×10^{-4} pCi/g) and suggests that an estimated value of C_i could range from 0 to about 5.0×10^{-4} pCi/g.

Table 3-5. Contributions of the six parameters that most affect C_i, the concentration of DU in deer tissue. The results of 10,000 iterations were used to generate the distribution of predicted values.

Parameter	% of Total Variance
DU Concentration in Soil, C_s	41.4
Airborne Dust (d_2 In Equation 3-20)	34.8
Weathering Time (t_w, Equation 3-21)	22.5
Feed Intake Rate (Equation 3-16)	0.8
Soil Ingestion Rate (Equation 3-16)	0.5
Water Intake Rate (Equation 3-16)	0.05

Of the three components described in Equation 3-16, soil ingestion contributes the most to C_i.. The magnitude of the soil ingestion term depends primarily on the DU concentration in the soil, and the soil ingestion rate plays a secondary role. Table 3-5 illustrates the dominance of C_s in the soil ingestion term. Two of the parameters that determine the amount of DU on the surface of plants are the mass of dust resuspended after impacts and the weathering time or the rate at which DU on surfaces is washed off to the soil. These two parameters are the next most important ones after soil concentration and account for about 57% of the variance.

While the contribution to C_i from DU taken into plants through roots from soil is small, there are other important factors. Equation 3-16 shows the effect of DU internally deposited in plants through plant roots. The small magnitude of the bioconcentration factor indicates that little DU is taken into plants through their roots. The amount of DU absorbed through plant roots would increase with higher soil concentrations, lower leaching rates, an increased percentage of DU in finely divided particles, and more-extensive root systems within the contaminated soils. Relatively high concentrations of U and other metals have been found in plants, but high plant concentrations occur in areas of much greater U availability than the impact area (Ibrahim and Whicker 1988).

In this model, the DU deposited on plant surfaces contributes more to C_i than the DU absorbed through the roots. Equation 3-20 shows the parameters that are used to calculate the amount of DU deposited on the surface of plants. The most influential parameters are the size of the area containing the available DU, discussed previously, and the biomass that is available as a depositional surface for DU and, therefore, as food for the deer. The interception fraction of the plants and the translocation factor are important but less so than the biomass and area of contamination parameters. The dependence of C_d on the area available for resuspension, the biomass, the translocation factor, and the interception fraction shows the importance of the density of the plants used for food and the amount of area covered by the plants. Interactions of different factors can significantly alter the model output if a large area for resuspension is used in the modeling or if a large biomass is associated with an area.

3.7. APG Field Sample Collection

3.7.1. Introduction

Concentrations of DU in the environment are likely to reflect the total amount of uranium introduced into the impact areas. Spatial patterns of DU concentrations also approximate the distribution of penetrator fragments in soils and sediment. The chemical instability of U metal in the ambient environment results in oxidation of the U fragments and the transport of soluble U constituents or small particles. Potential contamination of a large area such as the Main Front Firing Range is possible because of the amount of DU munitions tested at APG. Due to the nature of munitions testing, spatial and temporal concentrations in soils and sediments are expected to vary considerably.

It is unclear how much uranium would be taken up by living organisms, even though measurable amounts of DU are expected in sediments and water. Uranium has been shown to accumulate in living tissue with concentrations decreasing with successive trophic levels of the food chain (Kovalsky et al. 1967; Thompson et al. 1972; Blaylock and Witherspoon 1976; Mahon 1982). Consequently, we would expect to find the highest concentrations in phytoplankton and the lowest levels in carnivorous fish (e.g., sunfish [*Centrarchidae*] and white perch [*Morone americanus*]).

The total amount of uranium accumulated in aquatic ecosystems appears to be site-specific (Mahon 1982). Uranium uptake in the environment depends on the amount and chemical forms of uranium present in the environment, their spatial distribution, the type of biota present in the area, and individual physiological capabilities to bioaccumulate uranium, as well as abiotic factors such as the physicochemical characteristics of DU in water and the amount of DU that can bind to local soils and sediments (Osburn 1974 [in Mahon 1982]; Brenchley et al. 1977; Mahon 1982). To obtain information on uranium concentrations and their spatial distribution at APG, field samples were collected from many of the trophic compartments. Biota containing DU could indicate the bioaccumulation of corrosion products from penetrators that might represent toxicological or radiological hazards or both.