

Title:

**DEPLETED URANIUM RISK ASSESSMENT
FOR JEFFERSON PROVING GROUND:
UPDATED RISK ESTIMATES FOR HUMAN HEALTH
AND ECOSYSTEM RECEPTORS**

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**DEPLETED URANIUM RISK ASSESSMENT FOR JEFFERSON PROVING GROUND:
UPDATED RISK ESTIMATES FOR HUMAN HEALTH AND ECOSYSTEM
RECEPTORS**

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EXECUTIVE SUMMARY

This report is an update of previous risk assessments for exposure of humans and ecological receptors to DU munitions fragments at Jefferson Proving Ground, Indiana. New information about site hydrogeology and site characteristics have been made available since the last risk assessment by Los Alamos, and information from the NRC site assessment has also been discussed that could alter the magnitude of the risk estimates completed earlier. This report incorporates the new information and updates the models used to estimate the doses to humans and deer at JPG.

We used two scenarios for the risk estimates in this report. First is the occasional site user who is on the site about 6 weeks each year and who hunts deer and consumes the meat off site. The occasional user brings all food and water on site and the food and water is assumed uncontaminated with DU. The second scenario is a resident farmer who produces vegetable crops, dairy products and meat from the farm. Water from contaminated sources is used for livestock water and irrigation of crops, but drinking water is obtained from uncontaminated sources off-site. Exposure of deer to DU was by way of ingestion, inhalation and external exposure while the deer lived and foraged on the affected area. Deer were assumed to spend their entire lives in the affected area for these estimates.

The largest expected dose to occasional site users ranged from about 1 mrem y⁻¹ to about 16 mrem y⁻¹ and depended on the initial soil concentration of DU. The largest expected dose to the farmer ranged from about 2 mrem y⁻¹ to 44 mrem y⁻¹ and also depended on the initial soil concentration. Total doses to deer ranged from 1.4 x 10⁻² mrad d⁻¹ to about 3.1 x 10⁻¹ mrad d⁻¹ and were well below an exposure guideline and suggests that no adverse effects will occur in the reproductive cycle of the deer.

INTRODUCTION

Jefferson Proving Ground (JPG) was the facility where the U. S. Army Test and Evaluation Command (TECOM) conducted lot-acceptance testing of DU munitions. JPG was closed in 1995 under the Base Realignment and Closure Act (BRAC), and the lot acceptance mission was transferred to Yuma Proving Ground. Different risk assessments and radiological surveys were conducted at JPG to estimate potential adverse effects on humans and ecological receptors from exposure to DU munitions (Ebinger and Hansen 1994, 1996a, 1996b; SEG 1995, 1996). These studies provided information so that TECOM could pursue restricted release of the JPG facility under the agreements of a material license with the Nuclear Regulatory Commission (NRC). The information from these studies was also used to evaluate the possibilities of remediation of the DU impact area. The minimal risk to humans and ecological receptors from exposure to DU prompted the U. S. Army, the NRC, and other state and federal agencies to propose a land transfer that would make JPG a controlled-access wildlife refuge. The NRC has conducted an additional risk assessment, and there has been new information made available about the site, especially about the underlying geohydrology south of the firing line. The information used by the NRC and the newly available site characterization information was incorporated into the risk assessment framework used previously (e.g., Ebinger and Hansen, 1994). This report is the revised risk estimate for humans and ecological receptors at JPG.

The new information used in the risk estimate was taken mainly from two site characterization reports (Rust 1994, 1998). Water from aquifers underlying JPG did not meet water quality standards for drinking water. The poor quality of water from shallow wells was confirmed during field sampling of water well on the north part of JPG; water samples were repeatedly tainted with a sulfide smell or the strong odor or rotting eggs. The new water quality information also eliminated one of the scenarios used in the previous risk assessments that allowed use of shallow ground water for drinking water. Drinking water derived from shallow groundwater was eliminated as an exposure pathway in this report.

Measured permeability rates for different media that underlie JPG were also reported by Rust (1994, 1998). Testing done in the glacial till and the limestones beneath JPG was used in RESRAD predictions when appropriate, and DU migration through the till to surface water was considered the likely pathway based on the permeabilities of the geologic media.

METHODS

RESRAD Modeling

Version 5.82 of the RESRAD computer program was used to predict doses to humans exposed to DU fragments in the environment (Yu et al. 1993). The RESRAD program allows for evaluation of various pathways from the source term to man including external exposure and exposure from inhaled and ingested radionuclides. Two exposure scenarios were developed based on information from previous risk assessment efforts at JPG (Ebinger and Hansen 1994, 1996a, 1996b), radiological characterization data (SEG 1994, 1996), and site characterization data (Rust 1994, 1998). The first is an occasional use scenario where a hunter or hiker is in the affected area for approximately 10% of a year. The occasional site user is exposed to external radiation from the soil, inhalation of DU-contaminated dust, incidental ingestion of contaminated soil, and, in the case of hunters, consumption of game that foraged on the affected area and drank contaminated water. The second scenario is for exposure of a resident farmer who grows and consumes produce from the farm and raises livestock for meat and milk products that are consumed on the farm. In addition, the resident farmer could inhale DU-contaminated soil, ingest contaminated soil, is subjected to external radiation from the soil, and uses contaminated water for the livestock. In neither scenario does the site user consume drinking water from contaminated sources. Drinking water was removed from the scenarios because the quality of groundwater underlying the JPG area is of insufficient quality to be potable.

Several site-specific parameters were required for the RESRAD simulations. The most important was the initial concentration of DU in the soil. Several estimates of the inventory have been made during previous investigations of the risk of DU exposure at JPG. These estimates provided an upper and lower bound of the concentration used as the source term, and ranged from 16 pCi/g to 370 pCi/g. The details of how these values were derived are found in different reports (Ebinger and Hansen 1994, 1996a; SEG 1995, 1996) and will not be shown in this report. Each scenario was simulated with each soil concentration in order to estimate the maximum and minimum doses expected to humans.

Another parameter required for the RESRAD simulations was the distribution coefficient (K_d) or the ratio of radionuclide in soil water to that on soil particles. A large value of K_d slows the migration of

DU from the soil to groundwater, or effectively isolates the DU from the exposure pathways influenced by contaminated water. The value for K_d depends not only on the radionuclide but also on the chemistry of the soil and water at the site. Uranium is least soluble (i.e., immobile) in the U^{+4} state and more soluble in the U^{+6} state as UO_2^{+2} (Langmuir, 1978). The chemistry of the soils at JPG cover the range of conditions that would support either reduced (U^{+4}) or oxidized (UO_2^{+2}) uranium depending on the saturation of the soils with water. Reducing conditions are indicated by light colored streaks or mottles seen in soil profiles, and oxidized conditions occur in all soils, particularly at the surface. Thus, establishing a value or range for the K_d is difficult without specific experiments to measure the values. A large K_d would be expected if uranium from the penetrators had a large affinity for the soil particles, if reducing conditions existed, or both. On the other hand, small values would be appropriate in oxidizing conditions, when there is low affinity of uranium for soil minerals, or when carbonate and/or bicarbonate anions are found in the soil solution. Since the soils and underlying material at JPG weathered from glacial till and limestone, the presence of carbonates should be expected at least at depth in the soil profile. The values for K_d were bounded by the smallest expected value of 50 to a value of 800 in order to accommodate the uncertainty.

Soil parameters such as permeability, porosity, effective porosity and bulk density were also required RESRAD inputs. Permeability values for the glacial till and the underlying limestones were given in the Rust Reports (1994, 1998), whereas bulk densities and permeabilities for the soils were estimated from Soil Conservation Service reports (USDA, 1984). Estimates of the required parameters were considered adequate for the RESRAD simulations reported here because the predicted doses were not particularly sensitive to changes in these values. For example, changes of an order of magnitude in permeabilities or doubling or halving bulk densities had little effect on the predicted doses compared to significant changes in doses when small variations in K_d or soil concentrations were introduced.

Default values were used for food and water ingestion parameters for humans and livestock. Without specific values for JPG consumers, there was no reason to change the default parameters in these simulations. Appendix A contains a the listing of two input files, one for each scenario. The listing shows the default values for each of the parameters in the program.

Deer Model

A steady-state model was used to estimate the dose to deer that forage solely on the affected area at JPG. The model estimates ingestion of fodder that contains DU from root uptake and foliar deposition, consumption of contaminated drinking water, ingestion of contaminated soil, inhalation of DU-containing dust, and external exposure, then converts the concentrations to an expected absorbed dose rate. Since deer are the most commonly hunted animals at JPG, the steady-state model was designed to use deer as the receptor. Several sources were consulted for required parameters for deer including forage intake rates, amount of soil ingested, volume of water consumed per day, body weight, and other physiological parameters (Alldredge et al. 1974; Lautier et al. 1988; Mautz et al. 1976; Robbins 1983; Sample et al. 1997; Stahl, 1967). The development of the mathematical relationships for DU ingestion was discussed earlier (Ebinger and Hansen 1994; NCRP 1984).

Inhalation of DU-containing dust was estimated using an allometric relationship for the inhalation rate and an estimate of the concentration of DU-containing dust from the RESRAD model. Stahl (1967, also cited in Sample et al., 1997) showed that the inhalation rate is related to the body weight of a mammal by

$$I = \frac{0.54576 (BW)^{0.8}}{BW}$$

where I is the inhalation rate ($\text{m}^3 \text{d}^{-1}$) and BW is the body weight of the animal (kg). The mass loading for DU-containing dust in air was estimated using the RESRAD soil-to-air factor as a basis. The mass loading was assumed to be proportional to the soil concentration, so the default value of 10^{-4} g m^{-3} was modified by the ratio of the initial soil concentration to the lowest soil concentration of 16 pCi g^{-1} . Thus, the mass loading increased as the soil concentration increased. The inhaled DU concentration was calculated as the product of the inhalation rate and the mass loading, then was converted to an absorbed dose.

Exposure of deer to external radiation was also estimated. Since the external dose is due to - radiation from U-daughter decay, the external dose received by humans was similar to that received by deer and the conversion to an absorbed dose to deer was relatively simple. The external dose to humans

was estimated with RESRAD and was reported as a dose equivalent or equivalent dose depending on the choice of units. The receptor was assumed on site 100% of the time and there was no shielding due to time spent indoors for the RESRAD simulations. This is a realistic scenario for exposure of deer to external radiation. Cember (1996, p. 278-279) showed that absorbed dose and dose equivalent or equivalent dose are equal when X-rays, γ -rays or beta particles are considered because the quality factor or the weighting factor is unity. Thus, an external dose to humans is also the same as the absorbed dose for γ -emissions. We assumed that deer and humans behave similarly with respect to external radiation, so the external dose from RESRAD was used as the external dose to deer. The dose was converted to an absorbed dose (mrad d^{-1}) and included in the total dose to deer.

Scenarios

Two scenarios were used for the simulations presented in this report. An occasional user was assumed in the affected area for about six weeks each year. The occasional user brought all food and water for consumption onto the site from an uncontaminated source, and remained on site for the entire time or visited the site for a total of 6 weeks in a year. In addition, the occasional user hunted game from the affected area and consumed the game later. The game was assumed to feed on contaminated vegetation and water, and ingested contaminated soil. External radiation was included in the dose predictions.

The resident farmer scenario was developed to account for use of the affected area to produce food from produce and livestock. All food consumed was produced on site, and the farmer spent most of the time on-site. Drinking water was from off-site sources, such as the aquifer that supplies the City of Madison, Indiana, with water from the alluvial deposits of the Ohio River (Rust 1998). External radiation was also included in the predictions.

These scenarios were adapted from those used previously (Ebinger and Hansen 1994, 1996a; SEG 1995, 1996), and were considered reasonable for the kinds of activities that could occur on site after termination of the NRC material license. A farming scenario that included drinking water from shallow JPG aquifers was not used in this report because of the documented poor water quality at JPG.

RESULTS AND DISCUSSION

RESRAD Simulations and Predicted Doses to Humans

Occasional Use Scenario. The results of the RESRAD simulations from the Occasional Use Scenario are shown in Table 1. The Maximum expected dose ranged from about one mrem y^{-1} to about 16 mrem y^{-1} . As expected, the doses received by humans using the JPG affected area depended on the soil concentration. The pathways included in the assessment are external radiation from the soil, inhalation of DU-containing dust, ingestion of contaminated soil, and consumption of meat and fish hunted from the site. Game and fish on the site were assumed to be ingesting or living in contaminated water, and the DU concentration of the water depended on the initial soil concentration.

The maximum doses to occasional site users occurred at the start of the simulations and decreased with time in all simulations. Expected doses ranged from 0.7 mrem y^{-1} to 15.5 mrem y^{-1} to the occasional user, largely from inhalation of DU-contaminated dust and external exposure (Table 1). Maximum doses were independent of the K_d used in the simulations. The effect of uncertainty in the initial soil concentrations shows in the range of the expected doses and suggests that better estimation of DU concentrations in the soil would be important for decisions regarding land disposition.

Figures 1 and 2 show predicted doses when the initial soil concentration was 90 pCi g^{-1} , and Figure 3 shows the expected dose received from different pathways at the same soil concentration. Results are similar in shape but different in magnitude when any soil concentration was used as input. The total dose predicted from initial soil concentrations of 90 pCi g^{-1} was about 3.8 mrem y^{-1} (Table 1) and was mainly due to inhalation of dust that was contaminated with DU. The dose from inhalation was about 2.3 mrem y^{-1} or 61% of the total dose (Figure 3). External radiation from the decay of daughter products of U accounted for 1 mrem y^{-1} of the total dose or about 25%, soil ingestion and consumption of meat accounted for about 0.25 mrem y^{-1} or 6.5% of the total. All of the exposure pathways were water-independent which indicates that there was no component of the contamination or exposure due to DU dissolved in the water that was used by game animals. Thus, DU was transferred into muscle tissue of the game animals by resuspension of DU onto leaf surfaces that were foraged by game animals, by inhalation of contaminated dust, or by soil ingested during foraging. Exposure to DU by human ingestion

of drinking water was not allowed in the occasional use scenario, thus there was no component of the predicted dose to humans from drinking water.

The distribution coefficient, K_d , was important in predicted doses received after about 200 years of the simulation (Figures 1 and 2). In all cases, the predicted dose decreased from the maximum to near zero by about year 100, but there was a slight increase in predicted doses between year 200 through year 600 when the distribution coefficient (K_d) was set to a value of 50. The dose came only from the consumption of fish and was due to DU leaching through soil into the surface water in the affected area. This pathway was not important in the earlier years because the leaching time from soil into the surface water was relatively long. Figure 2 shows that no additional dose between years 200 and 600 was expected because DU did not leach into water due to the large value of K_d .

Table 1. Maximum doses expected for the Occasional User of the JPG affected area. Varying K_d from 50 to 800 had no effect on the maximum dose or when it was received.

Soil Concentration (pCi g ⁻¹)	Maximum Dose (mrem y ⁻¹)	Time of Maximum Dose (y)
$K_d = 50^1$		
16	0.7	0
90	3.8	0
270	11.3	0
370	15.5	0
$K_d = 800^1$		
16	0.7	0
90	3.8	0
270	11.3	0
370	15.5	0

¹ K_d of 50 is RESRAD default, K_d of 800 taken from SEG report (1996) and previous risk assessments (Ebinger and Hansen, 1996a).

Farming Scenario. Predicted doses for humans from the farming scenario were greater than those for the occasional use scenario because of the increased time spent on site and because of exposure from different pathways (Table 2). The largest expected doses ranged from 1.9 mrem y⁻¹ to 44 mrem y⁻¹ and depended on the initial soil concentration. The predicted doses from simulations with initial soil concentrations of 270 and 370 pCi g⁻¹ clearly exceeded the 25 mrem y⁻¹ limit suggested by the NRC. It should be remembered, however, that the initial soil concentrations from which the largest doses were predicted are estimates based on conservative assumptions. The range of the predicted doses also illustrates the effects of the uncertainty in the soil concentrations. Therefore, the predicted doses and consequences from allowing exposures that would result in these doses should be regarded with similar uncertainty.

Figures 4 and 5 show the total doses predicted from initial soil concentrations of 90 pCi g⁻¹ and K_d of 50 or 800. The pattern of the total doses is similar to that of the occasional use scenario in that the largest doses are predicted at the beginning of the simulation and decrease to zero by about year 100. Also similar to the results from the occasional use scenario is the small dose received between year 200 and 600 when the K_d is 50 (Figure 4). Table 2 shows the largest predicted doses at the four initial soil concentrations.

Contributions to the total dose from individual pathways are shown in Figure 6 and differ from the occasional use scenario. Doses from the farming scenario were mainly due to external radiation from the soil, followed by soil ingestion, inhalation of DU in contaminated dust, then consumption of produce, milk, and meat produced on site (Figure 6). The portions of the total dose from produce, meat, and milk consumption were due to DU that was resuspended on plants, inhaled by livestock, or from soil that livestock ingested. The dose from plants was largely DU resuspended on edible portions of produce that were then consumed by the resident farmer. The dose from meat and milk pathways comes from DU resuspended onto livestock fodder, ingestion of contaminated soil by livestock, and inhalation of contaminated dust by livestock, then incorporation into either muscle tissue or milk. Although water for livestock was taken from contaminated surface water, DU did not reach the surface water until about year 200 and was not a factor in the dose predictions until then.

Table 2. Maximum doses expected for the Farming Scenario. Varying K_d from 50 to 800 had no effect on the maximum dose or when it was received.

Soil Concentration (pCi g ⁻¹)	Maximum Dose (mrem y ⁻¹)	Time of Maximum Dose (y)
$K_d = 50^1$		
16	1.9	0
90	10.7	0
270	32.1	0
370	44.0	0
$K_d = 800^1$		
16	1.9	0
90	10.7	0
270	32.1	0
370	44.0	0

¹ K_d of 50 is RESRAD default, K_d of 800 taken from SEG report (1996).

Deer Model Simulations

Predicted doses to deer due to DU ingestion, inhalation, and external exposure were small and are shown in Table 3. Deer are the common game animals hunted at JPG, although hunting is not permitted in the area affected by DU penetrator impacts. However, it was assumed that deer foraged in the affected area and drank from contaminated water sources for their entire life span. This is probably over-conservative because deer have large home ranges larger than the affected area and would have foraged outside the affected area. The predicted doses are well below guidelines that suggest adverse effects to reproductive capability (IAEA, 1992).

Soil ingestion accounted for most of the U taken in by deer and ranged from 84% to 87% of the total U ingested (Figure 7). Ingestion from fodder accounted for 12% to 13% of the total U ingested, mostly from foliar deposition of resuspended soil. The rate of U Ingestion from water that contained 10

pCi/L DU was constant (about 37 pCi d⁻¹) but ranged from less than 1% to about 4% of the total U ingested because of the variation in initial soil concentrations in the simulations. Ingestion of DU comprised about 26% of the total dose predicted for deer at all initial soil concentrations (Figure 8). Inhalation of DU-contaminated dust was the largest contributor to total dose at about 38%. The external dose was about 35% of the total to deer.

Table 3. Predicted doses to deer from ingestion, inhalation, and external radiation from DU in JPG soils.

Initial Soil Concentration (pCi g⁻¹)	Predicted Total Dose (mrad d⁻¹)
16	1.4×10^{-2}
90	7.6×10^{-2}
270	2.3×10^{-1}
370	3.1×10^{-1}

UNCERTAINTIES

There are several sources of uncertainty in the various parameters that are used as inputs for the RESRAD simulations and the deer model predictions. Estimates of many parameters were used because site-specific values had not been measured in most cases. The effects of uncertainty in the estimated parameters on predicted doses are to add the uncertainties in parameter estimates into the predictions. The uncertainty in some parameters does not adversely affect the predictions, but for other parameters, such as the initial soil concentration, a small variation in the input value results in a significant change in the predicted dose to a receptor.

The parameter most affected by uncertainty is the initial soil concentration or the source term. Four estimates of the source term were used for this report and ranged from 16 pCi g⁻¹ to 370 pCi g⁻¹ in soils. These estimates bounded the predicted doses but did not allow establishment of a single point estimate of the dose to humans or ecological receptors. The range of concentrations in the source term underscores the need to establish the source term with more certainty. If only one source of uncertainty

could be reduced, a better estimate of the source term would provide the most increase in the reliability of the predicted doses.

The distribution coefficient, K_d , is also a parameter that can greatly affect the predicted doses to receptors, though not as much as the variation in the source term. Figures 1 and 4 show the resulting doses when K_d was 50, and Figures 2 and 5 show the same simulations at K_d of 800. At the largest K_d , DU was retained in the soil and none was leached to groundwater or surface water within the 1000-year time frame, whereas there was small but significant dose to humans after between years 200 and 600 when the K_d value was 50. There have been no measured K_d values reported for JPG soils, so even the range of values used in the simulations is in question. Measurement of K_d values for JPG soils would reduce the uncertainty in this parameter and in predicted doses.

Variation in site usage also significantly affects the predicted doses. The scenarios are based on estimated times spent on site, and any change in the usage times will affect the doses by the same magnitude. This is particularly relevant in the occasional use scenario and in the predicted doses to deer. The occasional use scenario has a hunter on site for about six weeks each year. Decreasing that time to three weeks would decrease the dose received by the hunter by about half. In the deer model, deer were assumed to forage only on the affected area for their lifetimes. When deer move off the affected area to forage, they consume uncontaminated fodder, soil, and water, and are not exposed to external radiation, thus the total dose received by deer would be less than if they forage only on the affected area. The predictions shown in this report probably over-estimate the doses received by humans and deer as a result of the time spent in the affected area.

The RESRAD program allows for soil erosion from the affected area, but the eroded DU is not accounted for in any of the dose calculations. Thus, eroded DU that is deposited in surface water such as Big Creek or any of the creeks at JPG is not included in the DU that is in water. The only means by which DU enters surface water and the dose calculations in RESRAD is by leaching through the soils and discharge of the DU-containing leach water into surface water. The uncertainty introduced by omitting the input of DU in to streams via erosion could be significant if large inventories of DU are in relatively erosive soils, and would under-estimate the total dose to humans and livestock in a simulation.

Variation in many soil properties including permeability, bulk density, erosivity, and porosity do not cause significant variation in predicted doses. The uncertainties in these soil properties usually cause less than one percent variation in the predicted doses. Likewise, many parameters that the user can supply such as dietary factors, non-dietary factors, and shielding factors change the predicted doses some but not more than about 5 to 10%. For these insensitive parameters, default values were used unless another value could be justified from site characterization data or knowledge of site processes.

CONCLUSIONS

The predictions presented in this report show that radiological doses expected in occasional site users ranged from about 1 to 16 mrem y^{-1} . The dose was largely due to DU-contaminated dust inhaled by the site user and radiation from DU in the soil, and the soil concentration determined the predicted dose. The predicted dose to a resident farmer ranged from about 2 to 44 mrem y^{-1} largely from external radiation, soil ingestion, dust inhalation, and consumption of contaminated vegetation. The predicted dose to the farmer also varied with the soil concentration. The fact that doses in the farming scenario exceed the 25 mrem y^{-1} regulatory limit should be considered in light of the uncertainty in soil concentrations of DU. The probability that soil concentrations are as large as 270 pCi g^{-1} or 370 pCi g^{-1} and the spatial distribution of large concentrations within the affected area have not been factored into the risk assessments but will influence the decisions of land use and disposition at JPG. It is possible that the farming scenario in itself leads to over-estimation of the actual dose because of conservative or unrealistic assumptions made during development of the scenario.

The largest absorbed dose predicted for deer foraging and living in the affected area was about 0.3 mrad d^{-1} , well below the suggested guideline of 100 mrad d^{-1} suggested by the IAEA (1992). The small doses to humans and deer using the JPG affected area indicate 1) that little if any remediation is needed to keep doses to these receptors within an acceptable range; and 2) that the JPG area could be effectively used as a controlled access refuge for animals. The large doses to humans suggest that the modeling assumptions associated with the estimates should be reviewed and the uncertainty in the model parameters should be reduced before more definitive conclusions are drawn about the risks of exposure and before decisions about land use are made.

The largest uncertainties in the predicted doses were in the initial soil concentrations and the values used for K_d . Uncertainty in other parameters did not significantly affect the predicted doses. Reduction of the uncertainty in soil concentrations and/or K_d would lead to reduction in the uncertainty in the predicted doses. Accounting for DU moving with eroded soil and allowing this part of the source term to affect surface water without leaching through soil first would also increase the accuracy in the predicted doses. Since RESRAD does not account for eroded radionuclides, a different computer model would be required to evaluate the effects of DU in the eroded soil.

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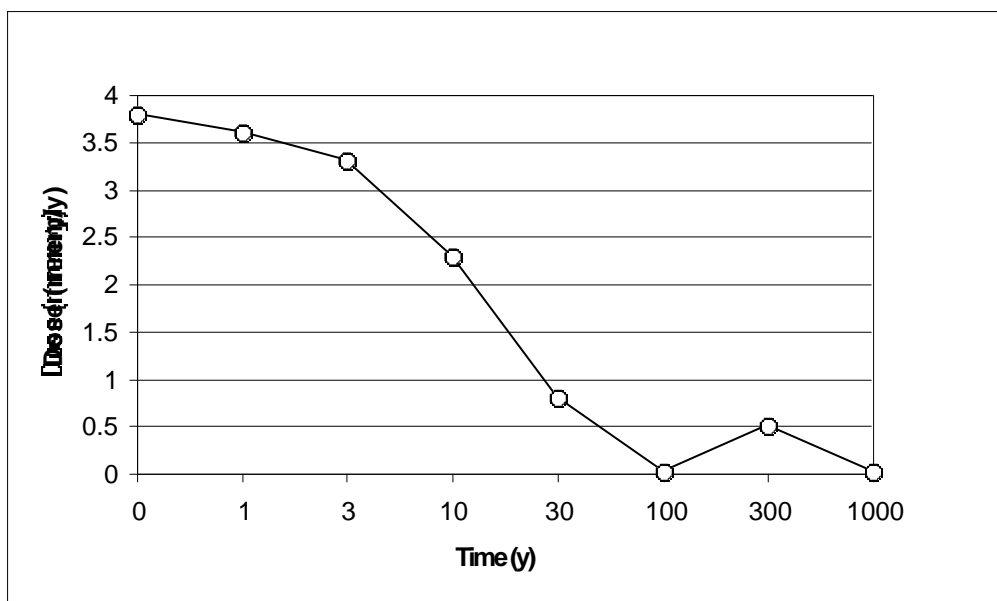


Figure 1. Total predicted dose to humans from the Occasional Use Scenario. Soil concentration 90 pCi/g, K_d of 50.

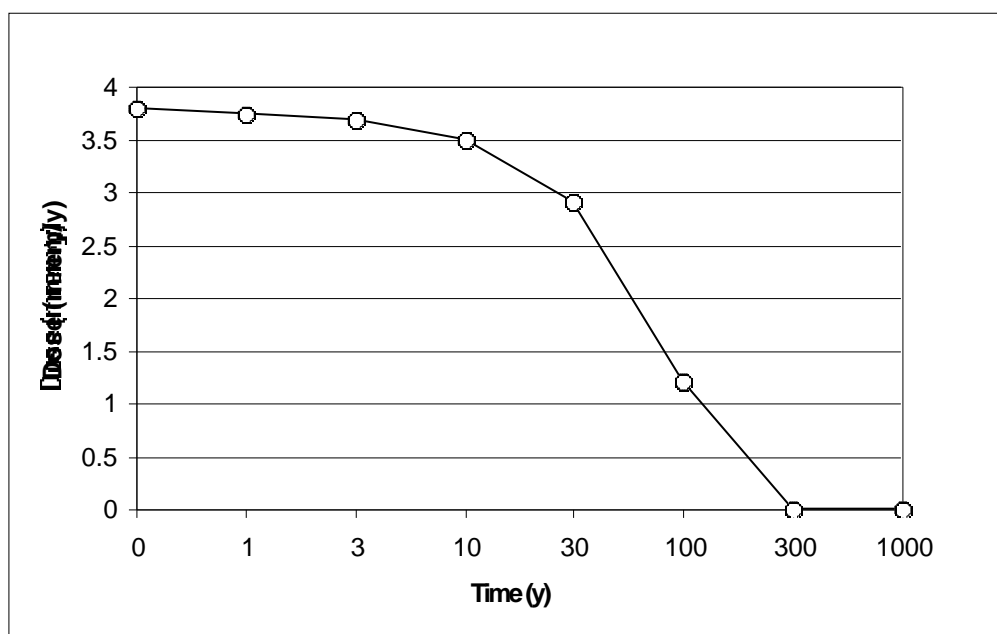


Figure 2. Total predicted dose to humans from the Occasional Use Scenario. Soil concentration 90 pCi/g, K_d of 800.

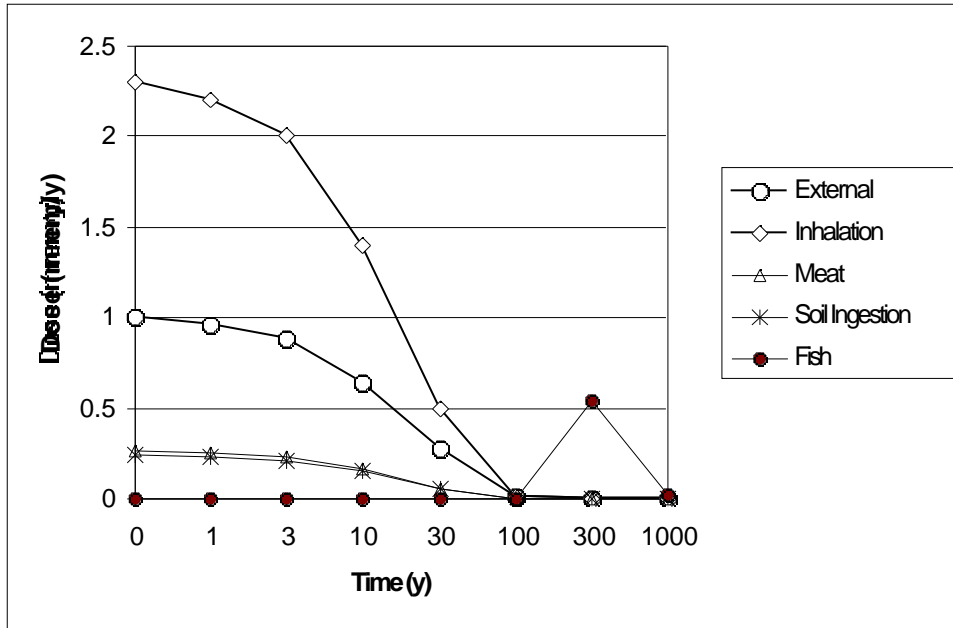


Figure 3. Predicted dose by pathway from the Occasional Use Scenario. Soil Concentration 90 pCi/g, K_d of 50.

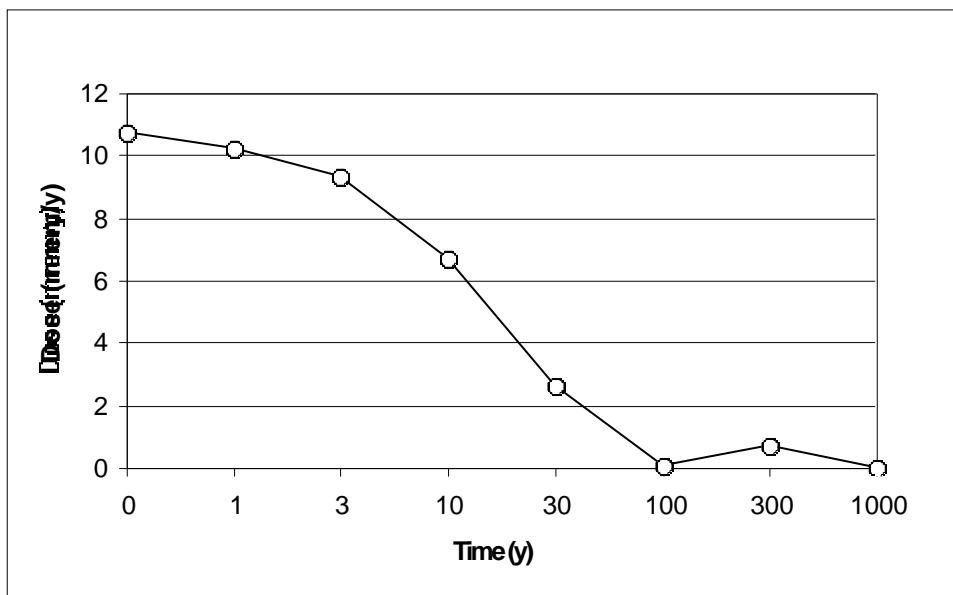


Figure 4. Total predicted dose to humans from the Farming Scenario. Soil concentration 90 pCi/g, K_d of 50.

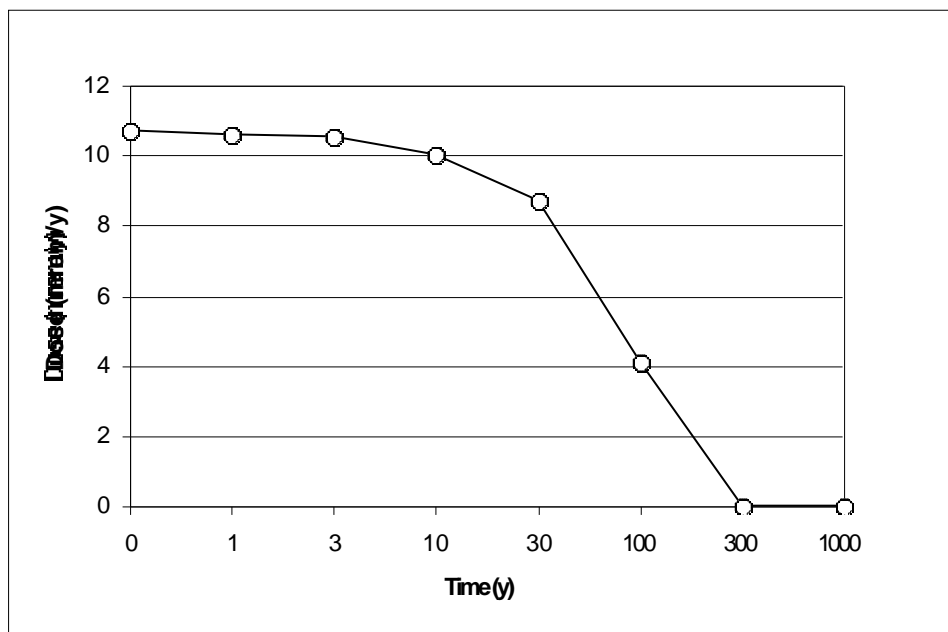


Figure 5. Total predicted dose to humans from the Occasional Use Scenario. Soil concentration 90 pCi/g, K_d of 800.

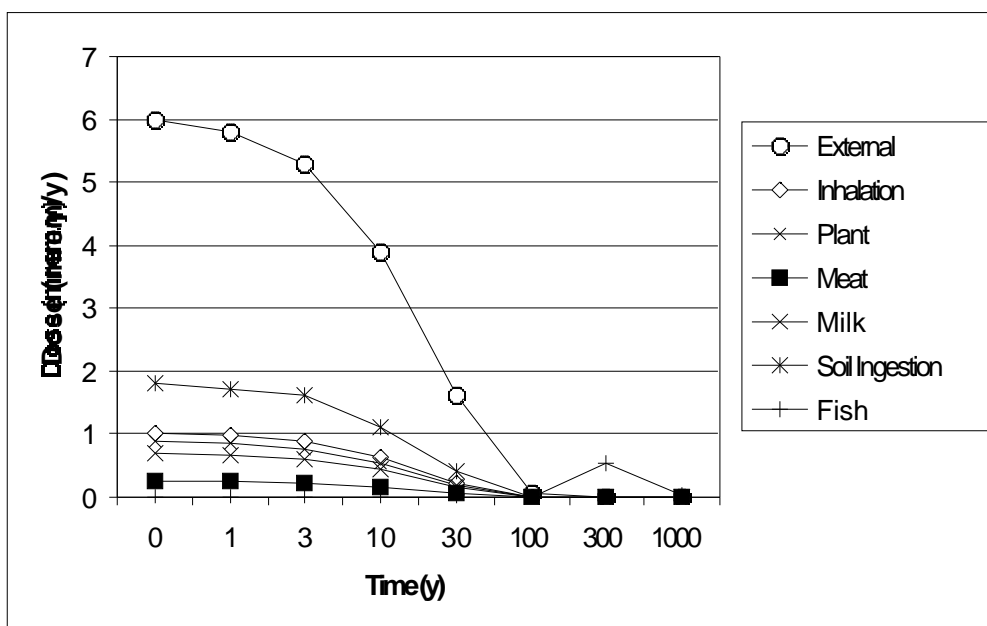


Figure 6. Contributions to total dose from various pathways. Soil concentration 90 pCi/g, K_d of 50.

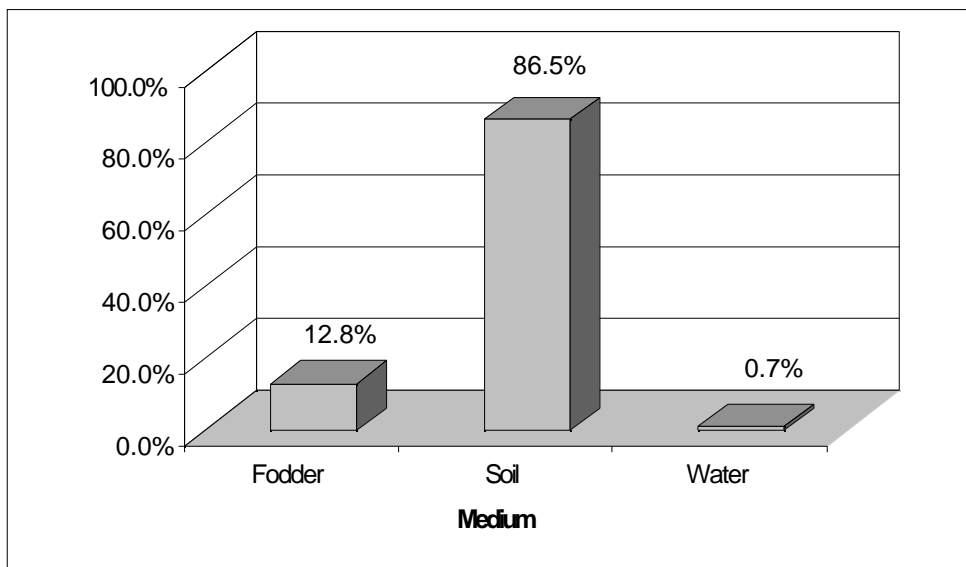


Figure 7. Contribution to total U ingested from fodder, soil ingestion, and water. Percentages are averages of modeling results from four initial soil concentrations.

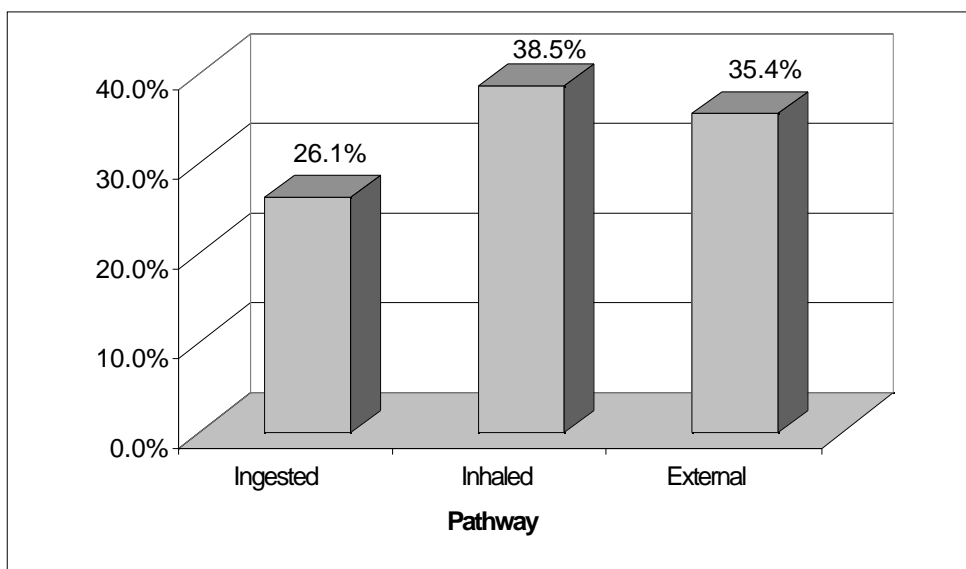


Figure 8. Percentage contribution to total dose from different pathways. Percentages are averages of modeling results from four initial soil concentrations.

Appendix A. RESRAD Input Files