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Title: DEPLETED URANIUM RISK ASSESSMENT AT ABERDEEN PROVING GROUND

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DEPLETED URANIUM RISK ASSESSMENT AT ABERDEEN PROVING GROUND

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Introduction

The Environmental Science Group at Los Alamos and the Test and Evaluation Command (TECOM) are assessing the risk of depleted uranium (DU) testing at Aberdeen Proving Ground (APG) (Ebinger et al. 1990). Conceptual and mathematical models of DU transfer through the APG ecosystem have been developed in order to show the mechanisms by which DU migrates or remains unavailable to different flora and fauna and to humans. The models incorporate actual rates of DU transfer between different ecosystem components as much as possible. Availability of data on DU transport through different pathways is scarce and constrains some of the transfer rates that can be used. Estimates of transfer rates were derived from literature sources and used in the mass-transfer models when actual transfer rates were unavailable. The models suggest little accumulation of DU in animals of successively higher trophic levels and illustrate the importance of soils and sediments in retaining DU in an unavailable form. The models also guide sampling in support of environmental monitoring and are important tools in estimating human health risks related to DU testing.

The objectives for this risk assessment are 1) to assess if DU transports away from impact areas; 2) to estimate how much, if any, DU migrates into Chesapeake Bay; 3) to determine if there are appreciable risks to the ecosystems due to DU testing; 4) to estimate the risk to human health as a result of DU testing. These objectives require that realistic ecosystem models be developed and used with any available literature and environmental monitoring data. The models can be refined with field data obtained through intensive sampling designed to determine DU concentrations throughout the ecosystem.

The approach to this risk assessment is through pathway analysis. Pathways, for the purpose of this discussion, are the possible ways by which DU can be incorporated into plants, soils, water, animals, and humans who use the area that is contaminated with DU. Pathways include complete food chains and parts of food chains such as water to fish to humans. Our method is to determine the inventory of DU on the impact site and use that inventory as input into a mathematical model of DU transport through the pathways in the aquatic ecosystem. The APG aquatic ecosystem includes fresh water areas inland from the bay a few kilometers and the brackish environment of the bay itself.

The risk assessment presented in this paper was conducted using little actual environmental monitoring data. Heavy use of literature values to estimate DU transport through the ecosystem resulted in large uncertainty in the predictions of DU transfer because literature values of input parameters covered a range of experimental and natural conditions. The results of this preliminary risk assessment were used to design sampling plans that will provided field and laboratory data. The field and laboratory data will be used to refine the mathematical ecosystem model and reduce the uncertainty of the predictions. Presented below are the results of the preliminary assessment and the plans to collect more samples that will provide the data for a more thorough risk assessment of DU in the Aberdeen environment.

Pathway Descriptions

Figure 1 shows the aquatic mas much as possible, model used for the preliminary risk assessment. This model was adapted from a carbon flux model of Chesapeake Bay developed by Baird and Ulanowicz (1989). The compartments we chose were based on known species at APG that are of commercial, recreational, or aesthetic importance. Thus, organisms like blue crabs and perch are included in the risk assessment.

The model simultaneously solves several differential equations for the flow or mass transfer of DU in the compartments of the model. DU flow is controlled by several metabolic, biological, or chemical variables including the rates fish filter water, biomass consumption by aquatic organisms, and defecation rates. Specific data on DU transfer into and from different compartments is needed but few of the needed data exist for DU and the organisms or processes of interest. Therefore, many values were extrapolated from published literature on othe contaminants. The aquatic model is inherently imprecise because of the extrapolations made. In most cases a range of values for the input variables was known or could be estimated with relative ease. From the ranges, probability distributions were derived so that mean values and expected standard deviations could be incorporated into the model. The ranges and probability distributions of the parameters allowed estimation of the uncertainty of the model. Using the ranges of input data also incorporated a reasonable amount of conservatism in the modeling while still being based on realistic phenomena.

DU transfer was simulated using the pathways shown in Figure 1. The results presented below are based on input data form the literature and estimations of most of the rate processes affecting DU transfer. Thus, this exercise does not replace field sampling, nor does it dictate the actual concentrations of DU in the different pathways. Instead, results of simulations suggest the magnitudes of DU concentrations and were used to design an efficient and cost-effective sampling plan for the aquatic ecosystem. Design of the sampling plan and the more thorough understanding of the ecosystem gained from field measurements would not have been possible without use of the aquatic ecosystem model.

Model Simulation Results

The aquatic model was run using an initial water concentration ("source" compartment or source term) of 1 pCi/L from DU. This value was bounded on the lower end using a national average U concentration in drinking water (Harley and Fisenne, 1990) and on the upper end by using U concentrations at about 10% of the proposed action level for radioactivity in water (Kocker, 1989; Zhao and Zhao, 1990). The water concentration is the most sensitive variable in the aquatic model and determines the magnitude of DU concentrations in other compartments. Data for the remaining input variables were either estimates of DU behavior based on other metals or ranges of actual DU transfer processes measured under a variety of experimental conditions. There were no actual field data incorporated in the aquatic model simulations.

The results of the simulations are summarized in Figures 2 and 3. First, the accumulation of DU decreased with higher trophic level in the ecosystem (Figure 2). This trend indicates that DU does not bioaccumulate in this ecosystem except in zooplankton, and that the highest concentration of DU in this ecosystem would be in the zooplankton at equilibrium or steady state.

Figure 3 shows the magnitude of the DU concentration in four compartments. As expected, the zooplankton have the largest DU concentration, whereas the other three compartments have little or no DU accumulation over time. Figure 3 suggests that little DU is making its way into the human food chain. Field data are required, however, in order to validate this observation. Figure 4 shows the DU concentration in aquatic sediments with time. Sediments tend to reach steady state much more slowly than the aquatic biota, and sediments have a much higher DU concentration than any other compartments. Sediment is determined to b the major sink for DU in this ecosystem.

These results suggest several characteristics of DU behavior in the APG aquatic ecosystem. First, only zooplankton should show any appreciable DU content when the ecosystem is systematically sampled and analyzed. Second, sediments should contain measurable DU since they appear to be the sink for DU transport. Third, the simulation results suggest little or no build up of DU in organisms of economic, recreational, or aesthetic importance. Low DU concentrations in species consumed by humans, furthermore, result in extremely low radiation doses to humans (<<100 mrem/y) and small toxicological doses (<1 μg/g in human kidney). Thus, there is little adverse effect expected from the testing of DU munitions at APG based on a conservative model using estimated input parameters. There is no direct evidence, however, that actual DU contents in organisms is higher or lower than the predicted concentrations. This evidence can only be provided from sampling the ecosystem compartments.

Sampling Designs

The simulations described above can be effectively used to plan intensive, systematic sampling of the APG aquatic ecosystem. Uncertainty and sensitivity analyses of the above model indicate that DU concentration in water is the most sensitive parameter and that zooplankton and sediments would sequester most of the DU in the ecosystem. Sampling water, sediments, and zooplankton would therefore be prudent to determine exactly how much DU transfers through the food chain. Sampling blue crab, rock fish, and other compartments are also indicated since these organisms are consumed by humans. Even though the simulations suggest that DU ingestion through consumption of fish is small, sampling must be done to confirm the prediction. The emphasis in field sampling, however, can be on the more sensitive parameters. A refined ecosystem model would incorporate data collected from field samples and will produce a more realistic estimate of DU ingested by humans and more complete radiological and toxicological dose calculations. The sampling plan for this ecosystem includes using more sampling resources on determining DU concentration in water, sediment, and in the zooplankton and fewer resources on other biota including fish, blue crabs, clams, and aquatic plants.

Conclusions

The ecosystem models developed for the DU risk assessment tend to be complex although realistic with regard to the flux of DU through the various compartments. Statistical distributions of the parameters used in the model showed that while the model itself is complex, there are only a few sensitive parameters that actually drive the model. Model simulations, therefore, indicate those segments of the ecosystem that should be more intensively sampled in order to determine the actual DU concentrations in the ecosystem. Since environmental sampling tends to be budget limited, the simulations provide a useful tool to target those parts of the ecosystem that would decrease uncertainty in predictions by providing the greatest insight to DU uptake by plants, animals, and to humans.

The simulations suggest that there is little DU ingested by humans who use the APG area commercially or recreationally. The simulations also show that there is little DU contamination in aquatic products from Chesapeake Bay. Accordingly, the models suggest there is little to no probability of adverse health effect due to consumption of DU contaminated products. Caution is advised, however, because this conclusion is based only on model simulations and not on actual data collected from the aquatic ecosystem.

Sampling plans designed to collect field data on DU transport through the ecosystem can be designed to collect most of the data from those parameters that are the most sensitive. Small changes in sensitive parameters result in large changes in the amount of DU ingested by humans, whereas variation in the less sensitive parameters tend not to change the predicted concentrations much. Using more sampling resources, therefore, on the sensitive parameters provides data for more detailed DU transport simulations as well as estimates of actual concentrations of DU available to animals and humans. Efficient and cost-effective sampling of contaminated areas assures that adequate assessments of potential health effects are conducted at the same time that resources to do the sampling are used wisely.

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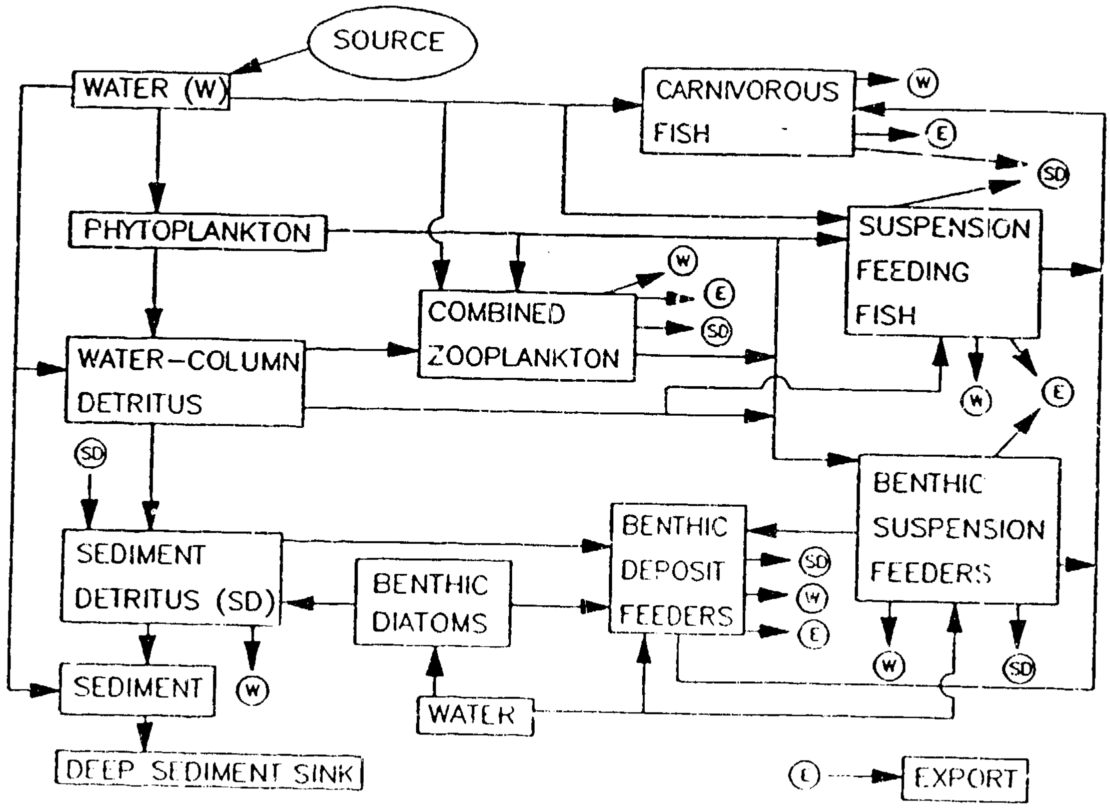

Figure 1. Schematic of aquatic model for APG ecosystem. DE moves from Source through various aquatic components.

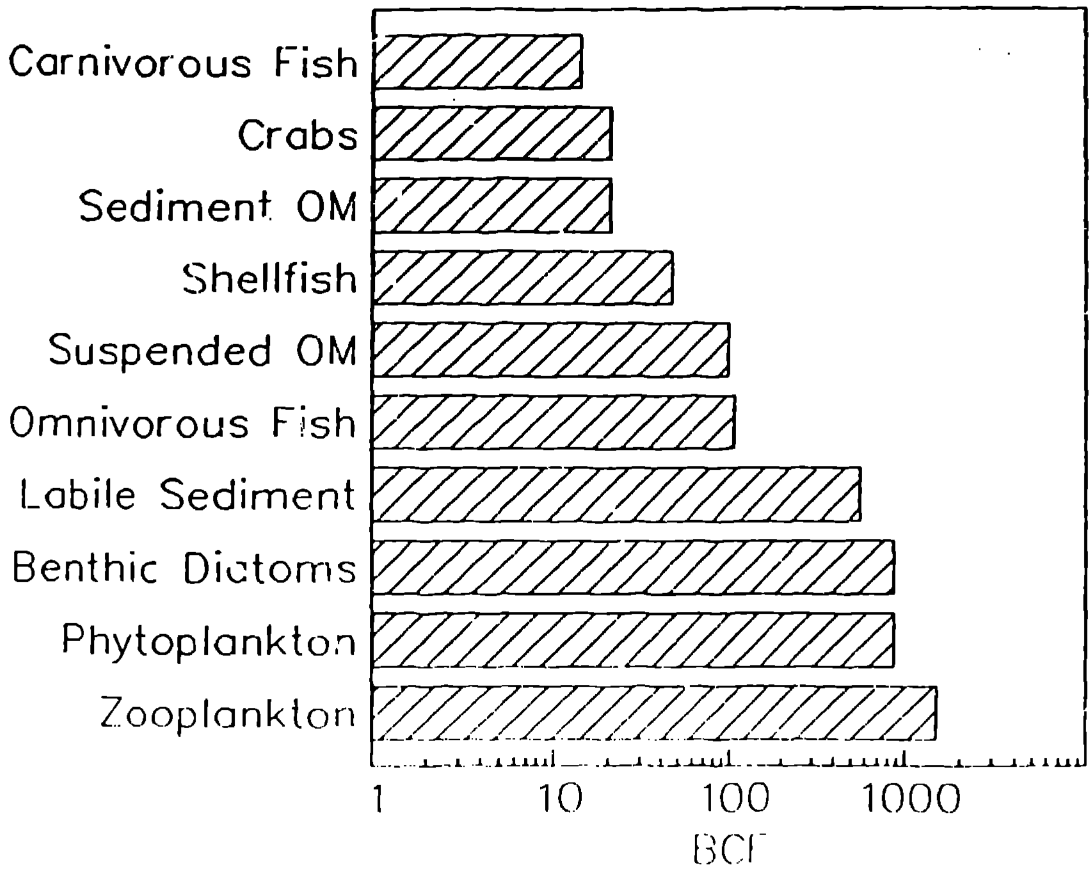

Figure 2. Bioaccumulation factors derived from aquatic model results. Values shown are averages of the bioaccumulation factors.

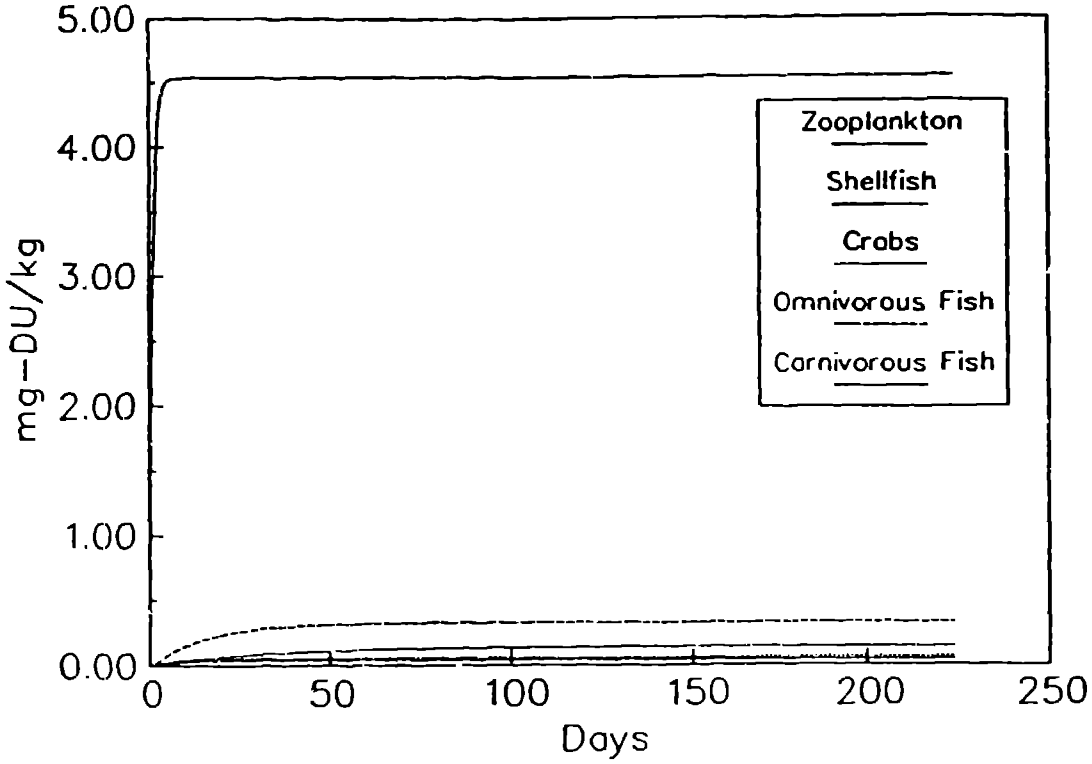

Figure 3. Results of aquatic model simulation. Graph shows DU concentration in zooplankton, shellfish, crabs, omnivorous fish, and carnivorous fish compartments with time. Steady state is reached within 10 days of simulation start.

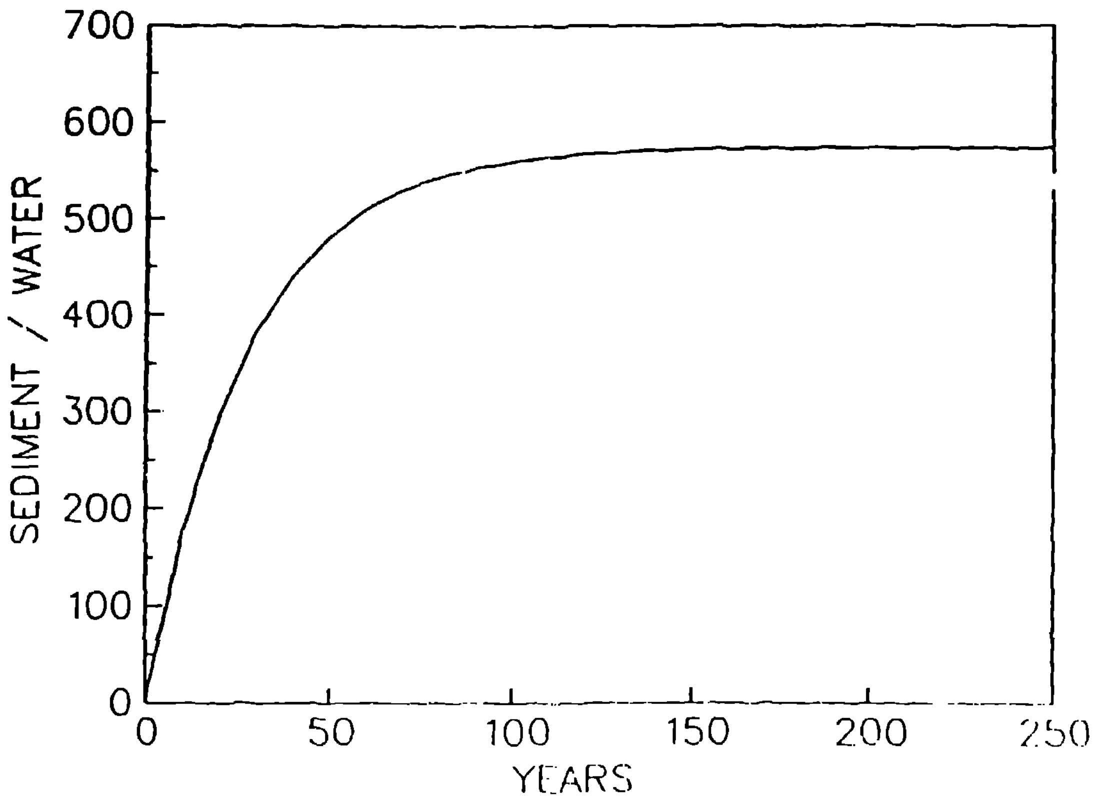

Figure 4. Results of aquatic model simulation. Graph shows DU concentration in sediment compartment. More than 50 years required to reach steady state, thus, sediment is a sink for DU.