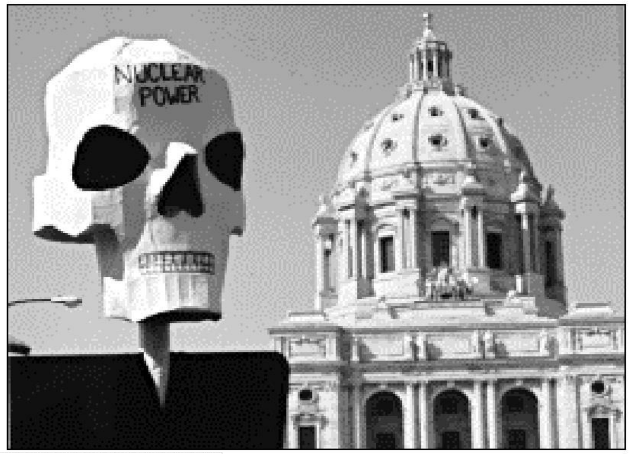
North American Water office

RADIATION DOSE ESTIMATION



Nuclear power plants routinely release radioactive materials to the environment. They dispose of radioactive gaseous wastes by dispersing them to the atmosphere, and they dispose of radioactive liquid wastes by dumping them into lakes, rivers and oceans. People are exposed to these materials. They receive radiation doses, and the size of the dose depends on the amount and type of radioactive material to which the person was exposed. Exposure to radiation can affect human health, and some people worry that radioactive materials have affected or will affect their health. The degree of health risk depends on the radiation dose.

Information needed to tell exactly what dose any one person received simply does not exist. Scientists can only estimate the amounts of radioactive contamination in the air, on the ground or on plants, or in water, at any given place and time. We cannot directly measure past or future radiation doses, which must be estimated or reconstructed. Estimation or reconstruction starts by collecting and reviewing information about the kinds and amounts of materials released by nuclear power plants. Researchers must then learn where released materials went or will potentially go in the environment, and how people were or will be exposed to them. Radiation doses also depend on factors unique to each person, such as location and diet at specific times, which cannot be recalled exactly. With this imprecise information, researchers estimate radiation doses people have or may receive.

Nuclear power plants routinely dispose of radioactive gaseous and liquid wastes by releasing them to our air and water.

Inside features

There will be some uncertainty about the true dose that each person actually received. However, with good information about radiation releases and monitoring data that tracks it as it moves through the environment, we can be fairly certain that our estimate for a particular person is a reasonable one. Unfortunately, while radiation releases from nuclear power plants are reported, there is very little information about where released radiation actually goes.

Without actual monitoring data that defines how radionuclides move through the environment, assessment of radionuclide releases to the environment requires the use of mathematical models that can describe the transport of radionuclides from a source through the calculation of dose to humans. In these models, the values that quantify the relationships between numerous media, such as the transfer of radionuclides between air, water, land, food, and human tissues, are referred to as model parameters. The results of radiological assessments are used to assist in decisions about the acceptability of releases of radionuclides.

Main Concerns to be Addressed in Radiological Assessment Models

When using these models in the past, the use of conservative assumptions caused model calculations to overestimate actual doses received by members of the public. These assumptions included the postulation of hypothetical individuals who resided at locations of maximum concentrations in air, water, or food, and whose behavioral and dietary habits were such that predicted doses would be higher than the expected average. Numerical guides and regulatory limits have been lowered substantially during the past several years, and emphasis is now being placed on removing conservative assumptions and increasing the "realism" of model predictions. Dose calculations are being tailored to the actual locations of residences and to site-specific aspects of food production and consumption by individuals living near nuclear installations. Unfortunately, most environmental transfer coefficients and dose conversion factors, which are model parameters, are not determined on a site-specific basis even though these parameters are the most variable and exhibit the most uncertainty in their estimation. For many radionuclides, appropriate data for parameter estimation are unavailable, and parameter values must be derived using scientific judgment. Attempts to improve the realism of model predictions by removing conservative assumptions without accounting for remaining uncertainties will increase the probability of underestimation.

Therefore, when models using realistic rather conservative assumptions result in dose predictions that approach regulatory standard by even an order of magnitude, the question arises: Is there a possibility that actual doses might exceed the standard? This question provides increased incentive for evaluating the uncertainties associated with current radiological assessment models.

Sources of Uncertainty

All environmental assessment models are inherently uncertain. At best they can only approximate real-world phenomena. Errors in model predictions, which lead to uncertainty in the results of any risk assessment, arise from a number of different sources. These sources can be categorized as improper model formulation, improper parameter estimation, and effects due to variability in the parameters caused by random measurements and sampling errors or natural variation.

Model and Parameter Uncertainties

Modeling uncertainties arise from the formulation of mathematical models used to predict doses, their associated risks, and the degree to which they accurately represent reality. Model and parameter biases are particularly suspect when predictions are made for conditions distinctly different from those for which the models and their data bases were initially developed. Such conditions are not uncommon. For example, models composed of data bases derived from short-term observations are often used to predict impacts in the distant future. Models developed from experiments involving flat terrain and short distances have been used to predict air concentrations of radionuclides over large regions of complex topography. Models that predict the uptake of radionuclides from soil by vegetation under a variety of field conditions are sometimes based on data obtained from a limited number of greenhouse experiments on a few plant species grown in potted soil. Models that rely on average dose conversion factors have been used to explain the presence of localized tumors and cancers even though the concentration of radionuclides in the body is not uniform, as human autopsies revealed in the case of plutonium deposition in the bone, lung, liver, and lymph nodes.

One way to address model uncertainty is to perform the analysis using a set of feasible alternative model structures. However, assessing modeling uncertainty is very difficult because it is often impossible to justify a set of plausible alternative models in light of available data, and to assign probabilities to these alternatives. One way to validate models and reduce associated parameter uncertainty, is to perform field tests of the models under the conditions of interest. However, this is rarely done due to several limitations, which is why, for example, the New Mexico Department of Health requested full access to all radiation testing and experiments conducted by and available to DOE and its contractors at nuclear complex sites in New Mexico.

Parameter Variability

Parameter variability as a source of uncertainty is related to the use of deterministic models. Deterministic models use a single value for each input parameter to produce a single prediction. These models ignore the effect of imprecise parameter estimation and system variability. For any assessment situation, model parameters are best represented by a range (or distribution) of values. This range translates into a range (or distribution) of model predictions. Failure to account for this range means that the predictions of deterministic models will be difficult to interpret when conservative assumptions have been removed from the calculation. To account explicitly for the imprecision in parameter estimation requires modeling approaches which are probabilistic rather than deterministic.

The Science of Probability and Dose Estimation

The science of probability measures and describes uncertainty. A probability is a number that tells us how likely a statement is to be true. What statements can we make about radiation dose estimates? We know that our estimated dose will not be the same as the true dose. But we need to show that our estimated doses usually are close to the true doses. To do this, we use interval estimates of radiation doses. Instead of saying that an estimated dose is 10 rad, we might say that we are quite certain the dose is between 5 and 20 rad. The wider the range, the surer we can be that the true dose is within it. However, if the range is too wide, it may not give us enough useful information. The range might include doses that cause little health risk to high risk. This is why scientists needs to study the amounts of uncertainty in all the factors that affect doses, and decide how much work should be done to reduce the uncertainty of those key factors. The ultimate goal of any dose reconstruction task is to produce dose estimates that are as accurate and representative as possible. Only in this way can environmental and health risks be reasonably calculated, proper policies adopted to develop short-term and long-term health and safety plans, and possible public health radiation effects be addressed.

NORTH AMERICAN
WATER OFFICE
PO BOX 174
LAKE ELMO, MN
55042
651-770-3861
www.nawo.org Ω gwillc@nawo.org