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Mr. Kieling:

In response to NMED's Public Notice No. 05-18, calling for public comment regarding Sandia National Laboratories' (SNL) Mixed Waste Landfill (MWL) Corrective Measures Implementation Work Plan (including fate and transport model), I would like to submit the following comments regarding the fate and transport model, published as "*Probabilistic Performance-Assessment Modeling of the Mixed Waste Landfill at Sandia National Laboratories*", SAND2005-6888. The intent in submitting these comments is to enhance the technical aspects of the modeling in a constructive manner.

1. General approach

The general approach taken in this effort is proper and commendable. Aimed at identifying appropriate locations and properties or constituents for long-term monitoring, the stochastic (probabilistic) modeling provides information for performing a sensitivity analysis, which in turn informs the monitoring program. This is an example of appropriate application of stochastic modeling, which is becoming more common around the Department of Energy (DOE) complex and within the Nuclear Regulatory Commission (NRC) and the Environmental Protection Agency (EPA). The Waste Isolation Pilot Plant (WIPP) Performance Assessment (PA) Group at SNL has been using the probabilistic approach to good effect for years, of course. While the general approach is acceptable, there are, however, several technical flaws that bring the overall results into question. These are identified in the following comments.

2. Inventory uncertainty distribution

The uncertainty distribution for the inventory of radionuclides in the MWL is undefended, applying a uniform distribution with a minimum at the values reported in SNL (1993) (see document references) and a maximum of only twice the minimum. No justification for this distribution is provided in the document, and in fact it is rather narrow given the uncertainties about the inventory apparent in the source document. First of all, it is highly unlikely that all inventory constituents share the exact same uncertainty distribution, so the uniform(x,2x) distribution seems *ad hoc*. Given that inventory uncertainty is often the greatest source of modeling uncertainty at other DOE sites, a more thorough analysis of these distributions should be performed. A common choice of distributional form, for example, is log-normal, which can be reflected in a statement such as "We believe with 95% confidence that the actual inventory is within a factor of 10 of the values stated in SNL (1993)." (Note that the values in that statement are made up for the purposes of illustration.) The current distribution would be stated as "We believe that the actual inventory cannot be less than the values in SNL (1993), and cannot be more than twice those values, with equal likelihood that they lie somewhere in between." This is a much more constrained statement, and would require a more rigorous justification. Such justification is not provided in the document.

3. Biotically-induced contaminant transport

Perhaps the most significant oversight in the contaminant transport (CT) modeling of the MWL is the lack of any contributions to transport by biotic activity, which should have been identified in the preliminary exercise of identifying significant features, events, and processes affecting (and effecting) CT at the site. Recent PA work at other DOE sites (Los Alamos National Laboratory -- see the 1997 draft TA-54 RFI by LANL; Nevada Test Site -- see Cochran et al.'s Greater Confinement Disposal Boreholes PA by SNL, 2001) has found that biotic activity in the form of plant uptake and redistribution of contaminants and animal translocation of bulk (contaminated) materials can be significant or even dominant modes of CT. In arid environments, plants tend to extend roots to surprising depths in search of water. Ants have been found to construct nests to depths of several meters. A cap thickness of a meter (the MWL PA document reports and defends a proposed thickness of 3 ft.) is ineffective at keeping these biota out of the waste. If allowed to intrude, ants and plants can contribute to significant CT from the waste to the ground surface, resulting in increased doses from surface exposures and larger source terms for atmospheric dispersion. It is suggested that the SNL MWL Model take these processes into account.

4. Translocation of radon-222 parents

The document includes the development of a method for predicting the ground surface flux of radon-222 (^{222}Rn) above the MWL, as a linear function of the concentration of its parent, radium-226 (^{226}Ra), at depth. This model is fine under the assumption that all the ^{226}Ra stays at depth, but if biotically-induced transport of waste materials is included as a CT process, this parent material (as well as its parents, such as uranium-238 [^{238}U]) will move into the cap itself and onto the ground surface. This does not fit the current radon diffusion model assumptions, and must be modeled by more sophisticated techniques.

5. Ingrowth of decay products of radon-222

Although the inclusion of the decay products of ^{222}Rn does not affect its transport, they must nevertheless be accounted for for the purposes of assessing dose from and exposure to radionuclides involved in surface processes. In particular, ^{222}Rn decays through a series of short-lived radionuclides (which would be accounted for in a summation of dose conversion factors) to lead-210 (^{210}Pb), which in turn decays through another series of short-lived radionuclides to stable lead. These decay cascades can produce significant doses, and should not be neglected in the dose assessment process. When coupled with biotic processes in the cap, even in a cap too thick to allow biotic access to emplaced waste, the CT link of diffusing ^{222}Rn to ^{210}Pb deposited in the cap to biotic uptake or exhumation should be expected to bring ^{210}Pb and its decay products to the ground surface and near surface. Where there is ^{222}Rn, there will be ^{210}Pb, and it needs to be included in CT and exposure pathways to potential future receptors.

6. External exposure pathway

A potentially significant exposure pathway was overlooked in the model: external exposures from radionuclides in the ground surface and near surface. This exposure, colloquially known as "shine", should be included along with inhalation of gases and particulates and incidental ingestion of soils by potential future receptors who would have access to the site. Dose conversion factors for the external exposure pathway can be found in the EPA's Federal Guidance Report 12 (Eckerman and Ryman 1993).

7. Institutional control and future receptors

Although the SNL MWL PA Model takes cues from PA guidance published by DOE in locating a future receptor next the MWL rather than directly atop the MWL, this assumption is difficult to justify given the local context of Albuquerque's aggressive growth. At some point over the period of performance (set at 1000 years), is it not likely that the MWL would be overrun by development? To be fair, it is an open question, and answers may be had in the form of expert elicitation. At any rate, it would be safer (more conservative, and arguably more realistic, policy notwithstanding) to assume that the MWL could be forgotten and simply built over. Precedent exists for building residential communities directly atop waste sites (recall Love Canal, which was never even forgotten). Institutional controls are likely to fail (see *Risk and Decisions*, National Research Council, 2005, and Institutional *Controls or Emperor's Clothes? Long-Term Stewardship of the Nuclear Weapons Complex*, Applegate and Dycus, 1998). Therefore, a reasonable potential future receptor scenario is that of a residence built directly atop the MWL. This would trigger the analysis of additional exposure pathways as well, such as exposure to indoor air with its elevated concentrations of gaseous radionuclides and volatile organic carbon (VOC) compounds.

8. Period of performance

The period of performance for this analysis is 1000 years, also taken from the DOE PA guidance. If this analysis were in support of a genuine DOE Order 435.1-style PA, such a period might be justifiable, but this analysis is not subject to these constraints. The rather arbitrary selection of 1000 years, rather than the previous DOE Order 5820.2A's recommendation of 10,000 years, or the National Research Council's recommendation of modeling to peak potential dose, is not justified. This is recognized at some level in the document, since hints are made about analyses considering concentrations and doses at times exceeding 10,000 years. The 1000-year and 10,000-year benchmarks may be useful for comparisons with other sites, but the peak dose analysis should also be included. This reviewer recognizes that at some point, the times required become so excessive (the peak ground surface radon flux and associated potential doses generated by a ^{238}U parent will occur some time between 10 and 100 million years) that modeling them becomes impossible, given considerations of climate change and even geological change, but such an analysis can still be useful in providing perspective on the long-term significance of waste disposal.

9. Future releases and decay products of PCE

The MWL has a significant inventory of tetrachloroethylene (PCE), a fairly common "bad actor" VOC. Transport and fate of PCE is modeled reasonably, including decay from biotic degradation (although future releases of PCE from as-yet unbreached containers seems to have been neglected). The decay products, however, are not modeled, and yet can be significant (in fact they should be regarded as being more significant) sources of cancer risk. PCE decays to TCE (trichloroethylene), which decays in turn to isomers of DCE (dichloroethylene), and then to VC (vinyl chloride). Some of these decay products have higher hazard indices than that of PCE, and cancer risk from them should be included in the model. It is also likely that biodegradation rates will vary with location in the model.

10. Conservatism

The model touts itself as being conservative in its assumptions, but this philosophy was applied inconsistently, with the location of a future residential receptor a case in point. But there is a more fundamental problem in attempting to be conservative, in that what is conservative is often not known, and cannot be predicted. For example, large infiltration rates may be considered conservative for a groundwater pathway, since infiltration will tend to drive contaminants down to groundwater faster. This is exactly not conservative, however, for surface pathways for the same reason. If contaminants are being removed from near-surface soils by infiltration of meteoric water (or the substantial water applied to residential landscaping), they are not available to contribute to exposures to potential receptors at the surface. If, on the other hand, infiltration is minimized, contaminants will tend to remain in the near surface, or at least in the waste zone, making a "conservative" assumption for surface receptors, but underestimating contributions to the groundwater pathway. In this example, the model could be run two different ways, each way being conservative for one of these pathways, but there are other perhaps hidden assumptions that will bias the analysis one way or another as well. This reviewer recommends abandoning the attempt to be "conservative" in favor of trying to be realistic in all assumptions. This actually works well with a probabilistic analysis, if input parameter distributions and CT mechanistic models are honest reflections of the modeler's state of knowledge, rather than some assumed bias attempting (and in some cases failing) to be conservative.

11. Monitoring of tritium and radon

The document suggests that monitoring of tritium and radon be conducted at the site boundary. This reviewer suggests that more valuable and interesting data are to be obtained by monitoring these constituents on the MWL itself as they emanate from the cap. Such monitoring will provide a more immediate and sensitive indication of gas emanation than can be provided by monitoring at the boundary.

12. *Ad hoc* sensitivity analysis

The sentivity analysis (SA) performed for this modeling captures the right idea of attempting to identify those model parameters and processes that most influence the results and recommending them for future monitoring. The SA, however, suffers from being rather *ad hoc*, rather than comprehensive. Details are missing, however, and this reviewer could be missing something, but it seems that the selection of parameters for SA may not have included all parameters in the model. Admittedly, a comprehensive SA, which would systematically assess the influence of every parameter in the model, is more difficult, but it is the only way to objectively determine what is sensitive. Selecting what might be sensitive based on professional judgment can result in missing sensitivities, which are often lurking in surprising places. In some cases, a poor choice of distribution can also mask what should be a sensitive parameter. For example, the unusually tight distributions selected for inventories (uniform varying only by a factor of two) may preclude the appearance of a constituent whose inventory really is more uncertain, and which really might be sensitive. It is recommended that a comprehensive SA be performed (and that the inventory distributions be revisited) or that, if this was done, that sufficient details be provided for the reader to understand the method.

I appreciate the opportunity for constructive input into this important contaminant fate and transport model.