2

UCRL-~~UCRL~~ 85462
PREPRINT

MASTER

MODELS AND CRITERIA FOR LLW
DISPOSAL PERFORMANCE

Craig F. Smith
Jerry J. Cohen

Modeling and Low-Level Waste Management:
An Interagency Workshop
Denver, Colorado

December, 1980

The logo for Lawrence Livermore Laboratory, featuring a stylized 'L' symbol to the left of the text 'Lawrence Livermore Laboratory' which is arranged in three lines and slanted upwards to the right.

Lawrence
Livermore
Laboratory

This is a preprint of a paper intended for publication in a journal or proceedings. Since changes may be made before publication, this preprint is made available with the understanding that it will not be cited or reproduced without the permission of the author.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

MODELS AND CRITERIA FOR LLW DISPOSAL PERFORMANCE

Craig F. Smith
Jerry J. Cohen

Lawrence Livermore National Laboratory, University of California
Livermore, CA 94550

ABSTRACT

A primary objective of the Low Level Waste (LLW) Management Program is to assure that public health is protected. Predictive modeling, to some extent, will play a role in meeting this objective. This paper considers the requirements and limitations of predictive modeling in providing useful inputs to waste management decision making. In addition, criteria development needs and the relation between criteria and models are discussed.

PREFACE

This paper is a compilation and summary of informal remarks delivered to the LLW Modeling Workshop at Denver, CO in December, 1980.

INTRODUCTION

Calculational models for the prediction of the consequences of waste management activities should be consistent with applicable criteria; however, definitive criteria for judging the effectiveness of low-level waste management activities have not, as yet, been established. Despite the absence of official criteria, there has been a considerable amount of work on model development. Aside from the development of definitive criteria, there are several other areas that should be defined before beginning model development. Model development requires consideration of what is to be predicted, how accurate it must be, and how it can be validated.

Over three hundred existing models applicable to low-level radioactive waste have been identified.¹ Yet, an extensive degree of effort in model development continues. Given this situation, one might logically ask the questions: Why isn't what we have good enough?; What are the specific gaps that need to be filled?; and How can we recognize an acceptable model should one evolve? These questions should be resolved before more extensive model development takes place. Failure to do so could result in an endless quest for some unattainable state of perfection.

*This work was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

PATHWAYS FOR EXPOSURE

The determination of what processes are to be modeled requires the identification of pathways for human exposure to low-level waste materials. Figure 1 illustrates the major pathways of concern.

Water pathways are generally believed to be the most important pathways for human exposure. The two forms of water pathways are surface runoff and groundwater transport. Climatic conditions (arid versus humid) strongly influence the importance of these pathways.

The airborne pathways can result from operational release during waste disposal activities, release to the air through erosion, and release in conjunction with the evolution of gases in the waste material. The erosional release pathway is a consideration primarily during the post-closure phase of the disposal operation.

Intrusion is another potential pathway for exposure to LLW materials. Human intrusion can be either intentional or inadvertent. In addition, plant and animal intrusion present potential exposure pathways.

Other pathways include combinations of the previously discussed modes. For example, surface runoff followed by subsequent wind transport could be considered.

An important objective should be the identification of pathways so trivial that attention can be more reasonably directed to those which have a greater likelihood of transporting significant quantities of hazardous material to the biosphere.

MODELING APPROACHES

Considering the many potential pathways for human exposure, a review of previous modeling studies indicates that perhaps an inordinate amount of effort has been devoted to the groundwater pathways. This is particularly true in light of previous studies^{2,3} which indicate that in terms of maximum individual exposures, the groundwater pathways constitute a relatively minor threat. Figure 2, taken from reference 2, shows the results of such a study.

There are several major approaches to the modeling of environmental transport. These include:

- Physical (Analytical)
- Empirical (Analog)
- Statistical (Probabilistic)
- Combinations

Physical models are determined by an analytical or theoretical description of the process being modeled based on first principles. Due to the infinite complexity of real world processes, physical models can never be exact predictive tools.

Empirical models are based on experimental data without the necessity for a detailed underlying theoretical basis. They represent an acceptance of the inability to thoroughly understand the process while making the best use of the data that we do have.

Statistical models use probabilistic inference to model the process. In some cases this is because the underlying theory is

probabilistic in nature, and in other cases it is a reflection of the uncertainty about input parameters or the detailed underlying physics. Models may also use a combination of these approaches.

MODEL LIMITATIONS

There are several well known limitations to predictive modeling. These include data limitations (where the complexity of the model may outrun the available data), computational limitations (where the complexity of the model outruns the computational capabilities), and developmental limitations (where time, economic, or other factors limit the desirability or capability for model development). In addition, the apparent search for perfection in predictive modeling is not only unnecessary, but may even be counterproductive.

There appears to be a tendency in model development to equate the level of complexity and detail with the credibility of the results. Modelers should be cautioned to keep in mind the famous GIGO admonition (garbage in, garbage out). Model complexity should never be used to disguise either lack of understanding of phenomenology, or deficiency in quality of data input. No degree of model complexity or precision can compensate for a lack of either understanding or information in the analytical process.

VALIDATION

In light of these limitations, it is important to consider the question of model validation. In the absence of experience (particularly the required observations over prolonged time periods) the process of validation is tenuous at best. How can we tell if a model works or not? One possible approach is to use natural analogs for the purpose.⁴

An application of this approach may be found in predictive modeling for the effects of Iodine-129 in radioactive waste. This radionuclide has been a source of concern because of its extremely long ($\sim 10^7$ yr) half-life.⁵ A recent study⁶ indicates that, as a result of groundwater leaching of high level waste, a maximum radiation dose of 3.3 rem/yr to the thyroid could result. Although we are unfamiliar with the details of the model producing this result, the prediction can be checked using the natural analog approach.

Assuming the high-level waste repository contained the waste from 10^3 GWe-yr of power production, it would have a total inventory of about 10^{13} gm of I-129. Further, assuming the repository was 1000 m deep and sited in a watershed of 10^4 km², the total natural iodine inventory in the top 1000 m layer of earth would be about 8×10^{12} gm. If the iodine in the waste leaches at a rate no more or less than that in the soil, then, at equilibrium, the average ratio of I-129/total iodine is 1.3×10^{-6} at the point of groundwater discharge. Because of its low specific activity, it can be shown that if all the iodine in the human thyroid were I-129, the maximum dose to that organ would be ~ 19 rem/yr. Therefore an individual receiving his

total iodine intake from that watershed could receive a maximum thyroid dose of only $(1.3 \times 10^{-6}) \times 19 = 2.4 \times 10^{-5}$ rem/yr, or about five orders of magnitude less than the predicted 3.3 rem/yr. Although such predictive models are based on admittedly conservative assumptions, it might be in order to question the degree of conservatism. Excessive conservatism, sometimes bordering on the absurd, can call the entire modeling procedure into question.

CRITERIA

As indicated previously, the development of models in the absence of definitive criteria is problematic. Previously proposed guidelines have tended to be vague. Such guidelines are not very useful in planning the development of models.

While radiological protection should be the overriding concern, the approaches to the required analysis is sometimes confusing. Emphasis on the maximum individual dose results in "worst case analysis". Two deficiencies of the "worst case" approach are: (1) it is highly dependent on the imagination of the modeler in selecting his assumptions, and (2) to the non-professional, the result may appear to reflect reality instead of an extreme and unlikely situation. An approach toward eliminating this problem would be to incorporate the concept of probability into the modeling process. This approach requires the determination of probabilistic criteria.⁷

In any case, definitive standards are vital. If you don't know what you are looking for, the chances are that you won't find it. In addition, predictive modeling capabilities should not dictate criteria - it should be the other way around.

SUMMARY COMMENTS

Definitive criteria are essential in the planning of waste management activities. In particular, the strategy for model development in support of the LLW program would logically depend on the prior establishment of criteria in order to ensure reasonableness and consistency.

Model development should take into account the question "how good is good enough?" in addition to pathways (what is to be modeled) and approach (how to do it). Recognizing the limitations of the modeling process, it should also be noted that models are tools to assist in the decision making process. They should not be considered to be an end in themselves.

REFERENCES

1. Mosier, J. E., et al., "Low Level Waste Management: A Compilation of Models and Monitoring Techniques," ORNL/SUB-79/13617/2, April 1980.
2. Cohen, J. J. and W. C. King, "Determination of a Radioactive Waste Classification System," UCRL-52535, March 1978.
3. Adam, J. A., and V. L. Rogers, "A Classification System for Radioactive Waste Disposal - What Waste Goes Where?" NUREG-0456, June 1978.
4. Cohen, B. L. "A Super Analog Computer for Evaluating the Safety of Buried Radioactive Waste," Waste Management-81, Tucson, 1981.
5. Kocher, D. C., "A Dynamic Model of the Global Iodine Cycle for the Estimation of Dose to the World Population from Releases of Iodine-129 to the Environment," ORNL/NUREG-59, 1979.
6. Croff, A. G., J. O. Blomeke and B. C. Finney, "Actinide Partitioning - Transmutation Program Final Report," ORNL-5566, June 1980.
7. Cohen, J. J., "Suggested Nuclear Waste Management Radiological Performance Objectives", NUREG/CR-0579, UCRL-52626, December 1978.

DISCLAIMER

This document was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor the University of California nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial products, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government thereof, and shall not be used for advertising or product endorsement purposes.

Figure 1

Environmental Pathways for LLW