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Introduction

The performance assessment of a nuclear waste repository demands much more in comparison to the safety evaluation of any civil constructions such as dams, or the resource evaluation of a petroleum or geothermal reservoir. It involves the estimation of low probability (low concentration) of radionuclide transport extrapolated 1000's of years into the future. Thus models used to make these estimates need to be carefully validated. A number of recent efforts[1,2] have been devoted to the study of this problem. Some general comments on model validation were given by Tsang.[3] The present paper discusses some issues of validation in regards to radionuclide transport.

Tracer Travel Time and Model Validation

Some of the current practices of model validation begin with considering the capability of a code and then searching for laboratory or field data with appropriate conditions to be used in a simulation study with the code. However, it is perhaps more logical to start off with the question what is the performance measure of the repository. In other words, we should first consider the key results that will measure the performance and then select available codes and models to calculate these results and check against field or laboratory data. Proceeding this way, one may find that specific measurement schemes may be required that are not the usual practice in field or laboratory studies.

The key performance measure of a nuclear waste repository is the travel time of possible transport of a tracer particle (radionuclide) from the repository to the biosphere. Factors such as changes in pressure and temperature fields around a repository are important, but are of concern only because of their impact to tracer transport and travel times. They are of course crucial in regard to repository constructibility and stability, but we are focusing on repository performance in this discussion.

Once we decide to look at tracer travel times, we need to identify two aspects: the appropriate processes and the model or geometric structures.[3,4] The processes include hydrothermal transport (buoyancy), chemical retardation, matrix diffusion, and hydromechanical effects. The last item refers to the change in flow rates due to mechanical closure or opening of fractures in the rock medium around the repository. This could be due to repository construction or thermal expansion phenomenon. Some of these processes, such as matrix diffusion, may be very slow processes which are not normally studied. However for estimation of travel times for 1000's of years, some of the slow processes may turn out also to be critical. Efforts have been underway to evaluate some of the processes involved in tracer transport.[5]

The other aspect is the model or geometric structures controlling tracer transport times. There are the boundary conditions, initial conditions and geological structures of the medium around the repository. Many of these structures may not be so well known. In particular the heterogeneity of the medium, especially if it is a fractured medium, introduces significant uncertainties into tracer travel times. If one is only concerned with pressure and temperature fields, the effects of these inhomogeneities are relatively minor. However, tracer travel times between two points A and B are strongly affected by, say, low permeability clay lenses between A and B. It is not unusual to observe that the tracer transport times between two points close together to be larger than that between two points farther part. This kind of observation presents great problems to model estimates and model validations, since it is almost impossible to know in detail all the heterogeneities between any two points A and B in the medium.

We investigated the problem and were able to show that these uncertainties can be greatly reduced if we do not consider travel times between points but rather those between line or areal tracer sources and tracer observations, where these lines or areas cover two or more spatial correlation lengths of the heterogeneity. In other words, we may admit that it is perhaps impossible for us to predict the tracer concentration at a point in space and at an instant of time. However, we may be able to predict, with reasonable limits, the average travel times between the total repository region and the biosphere. In the performance assessment of a nuclear waste repository, perhaps this is all that is required.

Conclusion

In model validation it is important to consider the proper performance measures, so that we are not addressing a measure that is too difficult to predict and that is actually not required for the performance assessment. In this paper we discussed the example of tracer travel times. It turns out that point predictions are perhaps not necessary, but averaged line or areal predictions are more feasible and may be all that are needed. This conclusion, which is very tentative, may have significant impact on the design of experiments that will be used for model validation.

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