

# EFAST Analysis Applied to a PA Model for a Generic HLW Repository in Clay

S.M. Spiessl\*, D.-A. Becker, A. Rübél

*Gesellschaft fuer Anlagen- und Reaktorsicherheit (GRS) mbH, Braunschweig, Germany*

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## Abstract

In this paper we investigate whether the EFAST method is suitable for use in long-term safety assessments of geological repositories for radioactive wastes. A generic test case for a HLW repository in a clay formation was selected. Despite the skewed and heavily tailed distribution of the model output, the EFAST results were surprisingly good compared to results previously obtained for a repository in rock salt. The important difference between the PA models in clay and salt is that the former produces a less skewed and less scattered distribution of the annual dose than the latter. As a result, the variance of the model output and the sensitivity indexes are more stable.

*Keywords:* sensitivity analysis; variance based analysis; FAST method; CSM plot; performance assessment

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## 1. Introduction

In a former investigation, we applied the EFAST method to two Performance Assessment (PA) models for a repository in rock salt. One of these PA models describes a repository for high-level waste (HLW/SF) and the other one a repository for low- and intermediate-level radioactive waste (LLW/ILW). Both models show typical important properties of a PA system. Firstly, the distribution of the calculated radiation exposure is highly skewed and heavily-tailed and typically spans over several orders of magnitude. Secondly, the systems show non-linear and non-monotonic behaviour. The PA model for the LLW/ILW repository additionally depends on discrete and quasi-discrete parameters.

Major deficiencies of FAST to deal with influential (quasi-) discrete input parameters and with highly skewed and heavily tailed outputs were identified with these two PA models which affected the stability of the sensitivity indexes (Bolado et al. 2010). This paper investigates whether the EFAST method performs better for a PA model for a HLW repository in clay which also shows some typical PA properties but does not include (quasi-) discrete parameters and produces smaller and less scattered peak doses. To verify the EFAST results, CSM (Contribution to the Sample Mean) plots were generated from the annual peak dose and results were compared to the EFAST results.

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\* Corresponding author. Tel.: +49-531-8012-272; fax: +49-531-8012-200.

E-mail address: [Sabine.Spiessl@grs.de](mailto:Sabine.Spiessl@grs.de).

## 2. Description of the PA model for a generic HLW repository in clay

The test case represents a generic repository for high level waste in a consolidated clay host rock formation. The rock properties and the transport properties of the radionuclides for both formations are described in Rübel et al. (2007). The overburden consists of a sequence of aquifers typical for Northern Germany and the according parameters were taken from Keesmann et al. (2005). For the reference scenario it is assumed that the mobilized radionuclides are transported by diffusion through the near field and the far field up to the water-bearing overburden and are retained by sorption. In addition, solubility limits affect the elements' total concentrations.

As model output the annual effective dose to an adult human individual is calculated with the software package EMOS. The computer code CLAYPOS is the clay module of the EMOS package for long-term safety analysis calculations for final repository systems. The EFAST samples were generated and analysed using SIMLAB 3.

Ten different samples were generated and used for the analysis. In two of these samples (1989 and 3965 simulations), 13 parameters were varied. In the rest of the samples (765, 1525, 2485, 4965, 9965 and 19995), only 5 out of the 13 parameters were varied to better study performance and sample size required for the EFAST analysis. The samples with 9965 and 19965 simulations were generated with different seeds.

## 3. Results and discussion

It becomes apparent that the diffusion coefficient in a specific region of the clay is the most important parameter, reaching a first order index (SI1) of up to 0.65. The next important parameters reach SI1 values of up to 0.12. Since there is nearly no release to the biosphere before  $10^6$  years, the results become significant only for very long time frames. The parameter importance of the EFAST analysis is confirmed by the CSM plot.

Between 500 and 1000 runs for each parameter are required to obtain convergence of the sensitivity indexes. The skewness of the distribution can be illustrated with the variance of the peak dose. Already very few runs (about 1.5 % of the simulations of each set) account to 50 % of the total variance. More simulations for each parameter may be necessary for the calculation of the indexes when all 13 parameters are varied as a result of the interactions.

The convergence of the indexes for the investigated PA in this study is surprisingly good compared to previous EFAST analyses for PA models in rock salt (Bolado et al. 2010). The important difference between the salt and clay PA models is that in the former model, the skewed distributions of the annual dose of the different simulations is much higher (factor up to 520) and more scattered than in the latter model. In other words, parameters of the PA model in the clay formation create a more continuous model output with narrower bandwidth. As a result, the variance of the model output is more stable, producing more stable sensitivity indexes.

## 4. Conclusions

This study indicates that the shape of the distribution of the model output can greatly influence the performance of the EFAST method. Reduced skewness and scatter of the output may ensure convergence of the sensitivity indexes.

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