A Bayesian Updating for an Earthquake Frequency Associated With an HLW Repository

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1. Introduction

Through this study, an imaginary disruptive event owing to earthquakes whose magnitude are over a certain limitation that could be set as required was considered. Earthquakes could result an increase of groundwater flow and a direct connection to MWCFs of the repository providing the shortest nuclide release pathway, which has been revised and extended from the previous study [1] in Bayesian point of view.

We still used the assumption that two principal parameters, the magnitude of the earthquake and the distance between a repository and its epicenter are enough to characterize earthquakes, and that they follow statistical behaviors of the distributions; a log-uniform distribution for the magnitude, ~uniform[5.5, 8.0] and a triangular distribution, ~triangular[0, 5, 25]km for the distance, respectively, which do not have any evidence yet for the time being though. Earthquake events used to be assumed to occur based on a simple Poisson distribution at a random time interval, but this time these are differently modeled.

Magnitude-to-distance ratios (M/T) over 0.1 for a flow increase in the MWCFs one time and/or direct MWCF connection when M > 7.5 are postulated in view of the long-term safety that might be disruptive enough to reduce the performance of the repository.

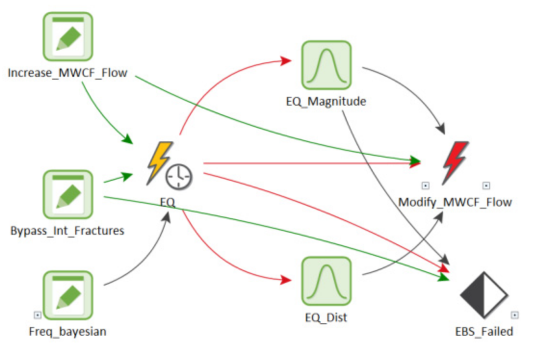

Fig. 1. GoldSim module for earthquake disruptive event with Bayesian updating routine.

In Fig. 1, a GoldSim model implemented for such an earthquake scenario is shown, in which the magnitudes and distances are generated by the distributions specified. The occurrence rates of earthquakes are modeled to be Bayesian updated sequentially in this study: In this model, the occurrence of earthquakes are assumed to follow a log-uniform distribution ~log-uniform[10^{-5}, 10^{-3}]yr^{-1} which seem rather appropriately chosen in view of historically recording, which has been Bayesian updated for three times sequentially with a likelihood which should and is assumed to be originated from recent measurements and expert elicitation, follows a Log-normal distribution, ~Log-normal[10^{-4}, 10^{-5}]yr^{-1}.

2. Bayesian Updating

Although reliable estimation of the distributions expressed as probability density functions for input parameters needs large amount of measured data, in most cases, especially in the safety assessment of the repository which is typically associated with long time span, observed data are usually limited resulting conventional probabilistic calculations rather uncertain.

In such case avoiding relying on such limited data available and/or some historical prior knowledge, a posterior distribution that could result from those prior distribution multiplied by supplementary distribution based on experts' elicitation form their beliefs and judgment regarding the parameter as well as recent measurements, as represented in Eq.(1).

$$p(\vec{\theta}|H_i,\ I,\ D) = \frac{p(D|\vec{\theta},\ H_i,\ I)}{p(D|H_i,\ I)} \cdot p(\vec{\theta}|H_i,\ I) \propto \mathcal{L}_\theta(H_i) \cdot p(\vec{\theta}|H_i,\ I) \quad (1)$$

which means the posterior is proportional to the likelihood times the prior showing the posterior has all the information from prior beliefs and data as an evidence, where: $\vec{\theta}$ =parameter vector, H=hypothesis or Model, I=information, D =data. Prior probability, $p(\vec{\theta}|H_i, I)$ is based on the output from previous observations and general historical belief and the likelihood, $\mathcal{L}_\theta(H_i)$ that represents a probability of obtaining data, D, for a given prior information I and a parameter set, $\vec{\theta}$.

For Bayesian updating, despite of its advantage, practical application might be very limited due to difficulty to get a posterior distribution easily or analytically except e.g., conjugate prior distributions. That is the reason Markov Chain Monte Carlo (MCMC) sampling algorithm widely used is adapted to the study.

3. Results

Through this study, for illustrative purposes, nuclide releases, frequency of the earthquakes were investigated under an earthquake disruptive event scenario in the hypothetical HLW repository system as an extended work done previously.[1]

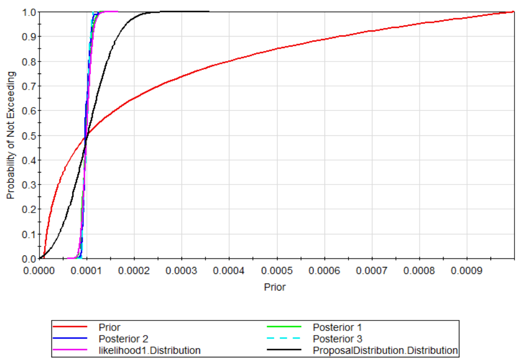

Fig. 2. Prior and posterior distributions compared to likelihood and proposal.

Assumed prior distribution and posterior distributions based on the very first prior probability and then sequentially used to substitute next two priors are shown in Fig. 2, in which a proposal distribution that is arbitrarily chosen and used for MCMC is also seen together.

With each posterior distribution probabilistic assessments for the dose exposure rates sequentially performed are also shown in Fig. 3, which represents probabilities for dose rates expressed in pdf and CDF, alternatively, by which broad distributions for the results become narrow down as Bayesian updated for the parameter of earthquake frequency, which shows four each total exposure rate in accordance with the first prior and three posterior distributions. In Fig. 4. realizations of the earthquake frequency from each sequential Bayesian updated distribution are also shown, being compared among each other.

Total exposure dose rates seem to migrate in turn to lower, rather less conservative values as priors are consequently replaced with previous posteriors, as is seen in Fig. 5.

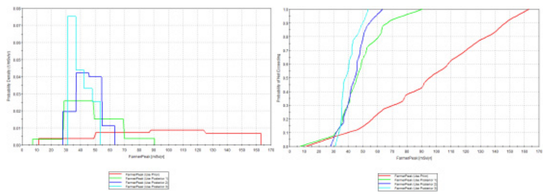

Fig. 3. Probabilistic calculation results in pdf/CDF for each Bayesian update.

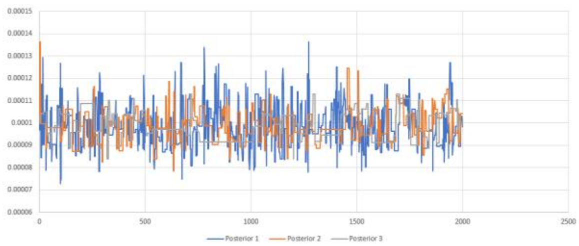

Fig. 4. Realizations of the earthquake frequency (yr^{-1}) from each sequential Bayesian updated distribution.

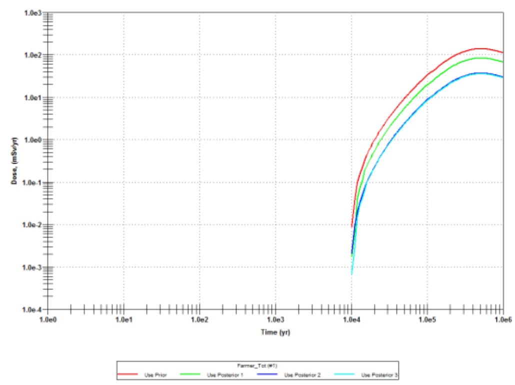

Fig. 5. Total exposure dose rates to farming exposure group for each Bayesian update for earthquake frequency distribution.

REFERENCES

[1] Youn-Myoung Lee et al., "An evaluation of an earthquake scenario for a pyroprocessed waste repository," Progress in Nuclear Energy, 66, 133-145 (2013).