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Bayesian estimation of a source term of radiation release with approximately known nuclide ratios

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We are concerned with estimation of a source term in case of an accidental release from a known location, e.g. a power plant. Usually, the source term of an accidental release of radiation comprises of a mixture of nuclide. The gamma dose rate measurements do not provide a direct information on the source term composition. However, physical properties of respective nuclide (deposition properties, decay half-life) can be used when uncertain information on nuclide ratios is available, e.g. from known reactor inventory.

The proposed method is based on linear inverse model where the observation vector $\mathbf{y}$ arise as a linear combination $\mathbf{y} = M\mathbf{x}$ of a source-receptor-sensitivity (SRS) matrix M and the source term $\mathbf{x}$. The task is to estimate the unknown source term $\mathbf{x}$. The problem is ill-conditioned and further regularization is needed to obtain a reasonable solution. In this contribution, we assume that nuclide ratios of the release is known with some degree of uncertainty. This knowledge is used to form the prior covariance matrix of the source term $\mathbf{x}$. Due to uncertainty in the ratios the diagonal elements of the covariance matrix are considered to be unknown.

Positivity of the source term estimate is guaranteed by using multivariate truncated Gaussian distribution. Following Bayesian approach, we estimate all parameters of the model from the data so that $\mathbf{y}$, M, and known ratios are the only inputs of the method. Since the inference of the model is intractable, we follow the Variational Bayes method yielding an iterative algorithm for estimation of all model parameters.

Performance of the method is studied on simulated 6 hour power plant release where 3 nuclide are released and 2 nuclide ratios are approximately known. The comparison with method with unknown nuclide ratios will be given to prove the usefulness of the proposed approach.

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