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Geostatistics cost-benefit analyses for classification of waste during initial radiological characterization

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Introduction

The objective of radiological characterization [1] is to find a suitable balance between gathering data (constrained by cost, deadlines, accessibility or radiation) and managing the issues (waste volumes, levels of activity or exposure). It is necessary to have enough information to have confidence in the results without multiplying useless data.

Geostatistics processing of data considers all available pieces of information: historical data, non-destructive measurements and laboratory analyses of samples. The spatial structure modelling is then used to produce maps and to estimate the extent of radioactive contamination (surface and depth). Quantifications of local and global uncertainties are powerful decision-making tools for better management of remediation projects at contaminated sites, and for decontamination and dismantling projects at nuclear facilities. They can be used to identify hot spots, estimate contamination of surfaces and volumes, classify radioactive waste according to various radiological thresholds, estimate source terms, and so on.

This paper deals with feedback experience over years in the use of geostatistics for cost-benefit analyses about material segregation integrating estimation uncertainty and decision support impact. This approach puts the emphasis on one interesting geostatistics output: probability of exceeding a threshold.

Mapping probability of exceeding a threshold

With input data and the spatial structure identified through the variogram, geostatistical techniques estimate the studied variable by a method similar to regression analysis called kriging (best linear unbiased estimator). This always includes a quantification of the associated uncertainty.

More advanced and sophisticated geostatistical methods, such as conditional expectation or geostatistical simulations, can be used to quantify different uncertainties—risk of exceeding the threshold, for instance. These estimates are powerful decision-making aids when classifying surfaces and volumes before decontamination starts (based on different thresholds as well as considering the remediation support impact). These techniques are widely used for radiological characterization for years now [2].

For probability results, the risk of exceeding a given threshold allows surfaces or volumes to be categorized in order to optimize radioactive waste management. Figure 1 illustrates the use of a probability of exceeding a threshold to map the misclassification risk.

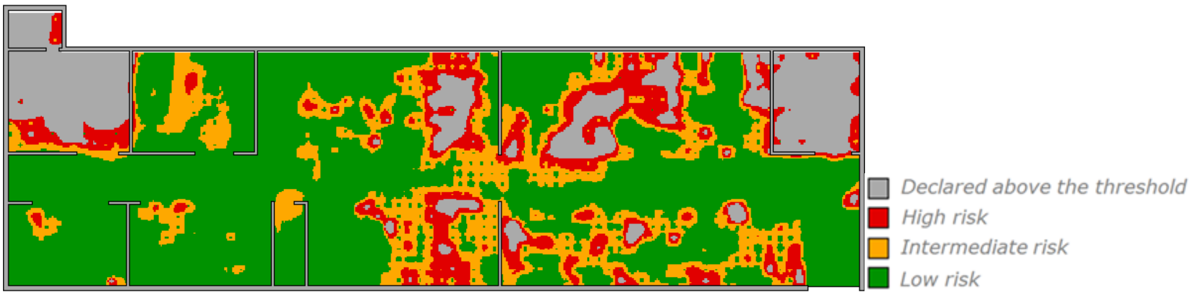

Figure 1: Map of the false negative risk (declaration of a contaminated area as clean).

This nuclear facility surface area is 800m². Surface contamination measurements were made using a regular grid with a 66cm mesh. Fifty sampling points were used to collect samples for laboratory analysis. Here, the risk under study is the false negative, in which an area is declared to be below the threshold using estimate results, but exceeds the threshold for real (but unknown) value. Depending on the threshold, acceptable risks may vary and corresponding surfaces change.

Global risk curve for decision

All stakes for the decision lie in the choice of the threshold and the probability level. From a global point of view, geostatistics provide risk curves for surfaces or volumes on the one hand and for accumulation (radiological inventory) on the other hand. The key issue is to limit false negative risk (leaving in place activity levels above the threshold) while handling false positive one (extra volumes due to over-conservatism).

When considering an objective function as the sum of the inverse cumulated frequency for probability levels and the normalised cost for remediation / decontamination, the corresponding curve generally present a global minimum that is a good balance between the two misclassification risks. On Figure 2, this optimum is around 20% probability, which corresponds to 10% of the volume.

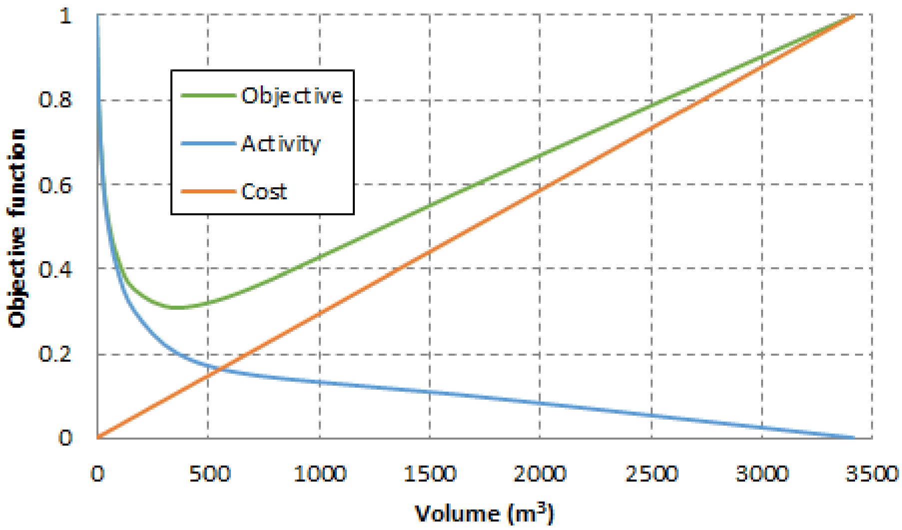

Figure 2: Objective function to identify optimum choice between activity reduction and cost management.

Sensitivity tests have been conducted on the weighting of the two parts of the objective function as well as for different thresholds and different spatial structures. Cost functions varying with depth have also been tested. In addition accessibility volumes can be integrated as well.

Objective function without global minimum have been produced for very low activity level (just around background levels). In that case, the decision is split into two extremes: remediate everything or leave everything in place.

Conclusion

The very basic idea to combine geostatistics outputs and technical and budget constraints leads to a very visual and helpful decision tool. Following ALARA principal, a balance between removed contamination and related treated volume can be discussed on sound results.

References

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