Chapter 13
A Geostatistically Based Probabilistic Risk Assessment Approach

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ABSTRACT

Most data required for cleanup risk assessment are intrinsically characterized by a high degree of variability and uncertainty. Moreover, typical features of environmental datasets are the occurrence of extreme values like a few random 'hot spots' of large concentrations within a background of data below the detection limit. In the field of environmental pollution risk assessment constitutes a support method for decisions inherent the necessity to carry out a procedure of remediation of an area. Therefore it would be adequate to provide the analysis with elements that allow to take into account the nature of the data themselves, particularly their uncertainty. In this context, this chapter focuses on the application of an uncertainty modeling approach based on geostatistics for the parameters which enter as input in the probabilistic procedure of risk assessment. Compared with a traditional approach, the applied method provides the possibility to quantify and integrate the uncertainty and variability of input parameters in the determination of risk. Moreover, it has proved to be successful in catching and describing in a synthetic way the relations and tendencies that are intrinsic in the data set, characteristics that are neglected by a traditional classical approach.

INTRODUCTION

The risk assessment is an efficient decision support method in the evaluation on the necessity to remediate a contaminated area; it serves as a tool for the definition of the concentration value to be reached by means of remediation interventions for human health protection. Nevertheless, in the execution of a risk assessment, the required data are characterized for the most part by a high degree of variability and in most cases, especially when a in-depth site assessment study is not carried out, also by a substantial level of uncertainty. Moreover, in many environmental applications, a few random

'hot spots' of large concentrations coexist with a background of data below the detection limit (censored observations) (Goovaerts, 1999). An alternative approach to the probabilistic analysis based on the methods of the classical statistics can be that of analyzing and quantifying the spatial uncertainty using geostatistical techniques. Geostatistics offers a series of extremely useful instruments to operate any decisional processes in that it allows to recognize the structures that normally characterize the spatial distributions of the studied properties.

This paper is aimed at providing a geostatistical method for modeling the uncertainty connected to the input parameters in a probabilistic procedure of risk assessment. It is structured in such a way: the first section will provide some legislative notions on risk assessment's role within the remediation procedure of a contaminated area, the intermediate sections will deal with how to treat uncertainties in risk assessment, whether with classical (stochastic), or geostatistical approaches. In this part the application of geostatistics is described for the delimitation of the potentially contaminated area, the determination of the Source Representative Concentration, and also of the optimal sampling designs for site characterization, an important phase of the remediation procedure. In the final part three case studies are proposed, in which the concepts explained in the theory are applied to contaminated areas.

The Risk Assessment in the Current Italian Legislation

The risk assessment procedure is considered by the current Italian legislation (D.lgs 152/06) as a support tool to establish first of all if it is necessary to remediate an area or not and, if so, the remediation targets to reach in order to annul eventual harmful effects for human health according to the predefined acceptability criteria. When an area is subjected to investigations in order to ascertain the eventual state of contamination, one decisive step concerns the delimitation of the potentially contaminated area, to be submitted to risk assessment and subsequently to eventual remediation treatments.

The current Italian legislation makes reference to two thresholds criteria of interventions: the former is the Threshold Concentration of Contamination (CSC) that is considered as an alert limit, that, once exceeded, makes it necessary to carry out a risk assessment; the latter is the Risk Threshold Concentration (CSR), that identifies the acceptable levels of residual contamination, on which to plan remediation interventions. An area is potentially contaminated if the pollutant concentrations exceed the CSC values (tabulated); it is declared contaminated if the pollutant concentrations exceed the CSR values, obtained by means of a risk assessment, to be carried out on the basis of the results of the investigations.

Uncertainty and Variability in Risk Assessment Data

The legislative decree n. 152/06 attributes a great importance to risk assessment and defines the general criteria for its elaboration; the risk is estimated in unquestionably deterministic terms and is expressed by a single numerical value. The principle at the basis of the procedure is that of considering always the "Worst Case" that assures conservative estimation values, in that it provides higher values than the average estimated ones, in favour of the environment and human health. Nevertheless, in the execution of a risk assessment the most conservative result is not always guaranteed as the data on which the analysis is based are characterized for the most part by a high degree of variability and often also by uncertainty. The character of uncertainty and variability of the risk assessment, an intrinsic property of this procedure, is explicitly recognized by the D.lgs 152/06 that reports: "the elaboration of the analytic results has to express the uncertainty in the concentration value determined for each sample..".

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