

CONTAMINATED SOIL RISK ASSESSMENT METHODS OVERVIEW

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ABSTRACT

Soil represents the upper part of the lithosphere, characterized by complex interdependencies, which plays a major structural and environmental role. Soil contamination can be perceived as the presence of man induced substances within a soil environment and represents one of our century's major environmental issues. Assessing the consequences and the related risks of soil contamination has been the subject of debates between policy-makers all around the globe. The direct result was an impressive number of risk assessment methods, based on different approaches, using multiple parameters and relating to various reference systems.

The present paper aims at reviewing the risk assessment descriptions within the most important countries in terms of risk assessment policy making. Analysis parameters such as United Kingdom, Norway, France, Germany, USA, Australia and New Zealand are also discussed.

The main objective of the current research is to identify key elements that are present in all risk assessment methods and to investigate the possibility of a world-wide harmonized approach. This comprehensive overview outlines the most recent updates in terms of risk assessment and may be further used as a starting point when analyzing risks related to a contaminated site.

Keywords: Soil, contamination, risk assessment methods

INTRODUCTION

At international level an impressive number of methodologies exist in order to assess risks generated by altered soil. The concept of "soil alteration" defines the process through which the basic characteristics of soil are modified, in a way that restricts the fulfilment of its basic functions. Soil alteration usually occurs due to anthropogenic activities, such as agricultural practices or industrial activities. The most common alteration processes are: contamination, compaction, erosion, salinisation and loss of fertility. Taking into account the type of soil alteration, risks are assessed based on the soil's previous functions, therefore the applied methodologies are based on different parameters and relate to various reference systems (HANSSON, 2007). In order to assess risks related to soil contamination with chemical compounds several approaches can be applied. These generally include a qualitative and a quantitative dimension. Although risk assessment methods may be based on similar steps, major differences can appear due to legislation, the degree of complexity and the expertise of the developers.

The presumption regarding a potential contaminated soil represents the triggering step of a soil risk assessment (FERGUSON ET AL., 1998). A qualitative estimation of risks from an ecological, social and financial point of view is then conducted. Afterwards, further instrumental investigations need to be conducted in order to properly estimate the related consequences. The results obtained represent raw input data for the quantitative risk assessment. They can be compared with the reference values, or can be used in mathematical formulas for determining risk indicators. This process leads to a quantification of risk, and a degree of acceptability is stated. In the end, risk values need to be integrated in exposure models and correlated with

scientific existing data (BIANCO, 2008). The results of the risk assessment are disseminated and taking into account public risk perception the best available remediation methods are discussed. In a general form, the main phases of a risk assessment can be represented through a block diagram, as seen below in figure 1.

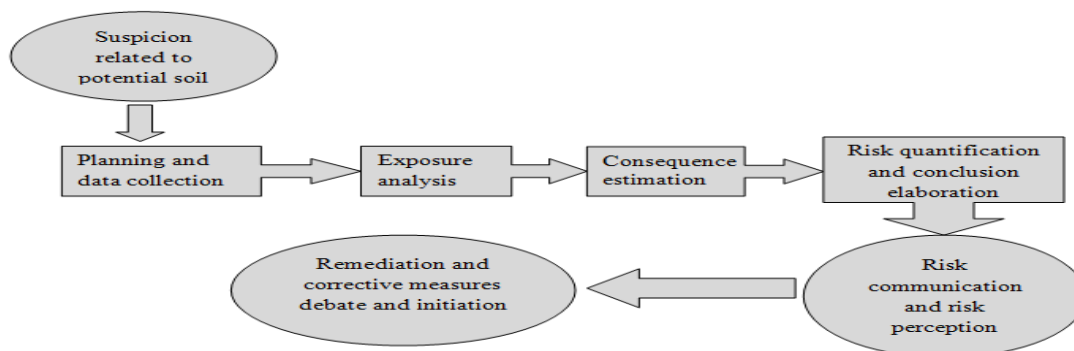


Figure 1. Block diagram representing the main phases of a contaminated soil risk assessment (Adapted after FERGUSON ET AL., 1998)

The sequence of phases constituting the risk assessment block diagram in figure 1 represents a starting point that can be adapted or modified based on the specific purpose of the research conducted. Various methods and methodologies aiming to assess soil contamination related risks and its involved consequences have been therefore elaborated. Policy-makers all around the globe proposed and applied risk assessment methods that vary substantially. The current paper will take into discussion several risk assessment methods underlining different parameters and various reference systems.

MATERIALS AND RESEARCH METHOD

In order to gain a solid point of view and to properly highlight both commonalities and differences between risk assessment methods, the policies and practices used in various countries were analysed. The major “best-practice-establisher countries” in the field of contaminated sites are taken into discussion and risk assessment approaches in United Kingdom, Norway, France, Germany, USA, Australia and New Zealand are reviewed. For this purpose, specific practices were compared and the results have been structured in two tables. The first table highlights the stated description of risk assessment in the country under discussion and offers brief information about structural risk assessment parameters that cannot be overlooked. Specific observations have been made based on the developer’s point of view. The second table underlines each country’s particular approach in themes of risk assessment with a particular focus on uncommon and original items. In the end, the possibility of adapting a global integrated approach is taken into discussion and conclusions are formulated based on the current state of facts.

RESULTS

The relevant information for the present study was extracted during a literature survey conducted upon risk assessment practices used in seven countries that play a major role in setting environmental policy trends. In order to be properly compared and analyzed, data was structured in *table 1 and table 2*. *Table 1* contains data referring to the document that regulates risk assessment procedures in the country under discussion, a short description of risk assessment, representing the country's point of view upon the subject and the most important parameters assessed. *Table 2* includes a summarized risk assessment approaches.

Table 1. Structured risk assessment information

Country, Document name, Elaborator	Description of risk assessment	Assessed parameters
United Kingdom Model Procedures for the Management of Land Contamination elaborated by UK Environmental Agency	Risk assessment is an essential component in achieving effective management of the risks from land contamination which provides a structured mechanism for identifying risks and making judgments about the consequences	Type of contaminated site Location Contaminants Physical conditions on or around the site Characteristics of receptors
Norway Guidelines for the Risk Assessment of Contaminated Sites, elaborated by the Norwegian Pollution Control Authority	Risk assessment of contaminated sites is the analysis conducted based on identified contamination and the present and future activities that take place the affected area.	Contaminant concentration Exposure and pathways Type of receptor Acceptance criteria Contamination expansion
France The French approach to contaminated-land management elaborated by the Ministry of Environment and Sustainable Development	Risk assessment of polluted sites represents an impact evaluation of polluting chemical substances on man, water resources, and the environment.	Contaminant presence Transfer mode Target Extension and mechanism of pollution Exposure scenarios
Germany Federal Soil Protection and Contaminated Sites Ordinance elaborated by Federal Government	Risk assessment is the process that serves for the determination of amount and spatial distribution of pollutants, possibilities for their spread and intake by humans, animals and plants.	Exposure Pathway Background content Amount and type of pollutant

<p>USA Framework for Cumulative Risk Assessment elaborated by U.S. Environmental Protection Agency</p>	<p>Risk assessment is a characterization of the nature and magnitude of health risks to humans and ecological receptors from chemical contaminants and other stressors that may be present.</p>	<p>Nature and extent of contamination Fate and transport processes Exposure Toxicity of chemicals</p>
<p>Australia The use of Risk assessment in contaminated Site Assessment elaborated by the Department of environment, Government of Western Australia</p>	<p>Risk assessment is the process of identifying, and evaluating the risks to health and the environment that may be posed by the condition of a site.</p>	<p>Contaminate type Hazard posed Exposure Risk perception</p>
<p>New Zealand Risk Assessment for Contaminated Sites in New Zealand elaborated by Natural Land Research Centre</p>	<p>Risk assessment is an estimation of the risk level and the probability and magnitude of an event that might occur.</p>	<p>Problem Identification Receptors Exposure Toxicity</p>

Taken into account the information presented in table 1 it can be stated that even though risk assessment is expressed in many different ways the overall perception in the countries analysed is very much alike. The general idea that can be extracted is that risk assessment is perceived as a process, analysis, estimation or characterisation that serves at the determination of the consequences related to a possible contamination. The main parameters that are analysed on a regular basis have when conducting a risk assessment been grouped in the following categories: contaminant characteristics, receptor type and risk perception, exposure to contaminants, site conditions, transfer pathway and possibility of contamination extension and mechanism of pollution. Their importance has been estimated by analysing the frequency of their appearance in the risk assessment methods compared in the present study, and illustrated in figure 2.

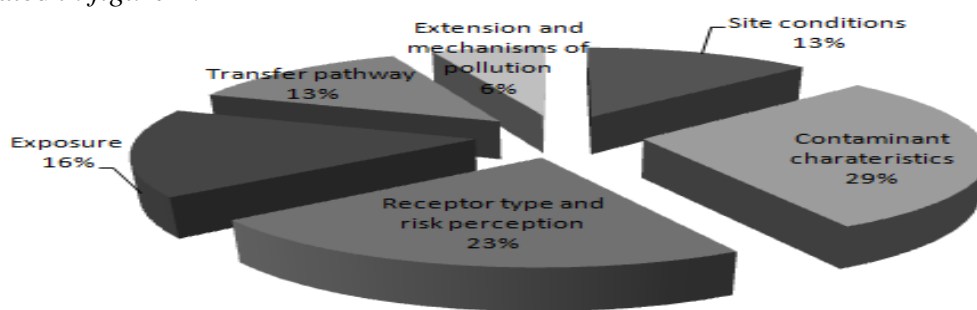


Figure 2. Main parameters analyzed during a risk assessment

In order to further investigate the possibility of conceiving and implementing an integrated harmonised risk assessment approach, the standard methods applied in the countries under discussion were summarised as shown in the table 2.

Table 2. Summarized risk assessment approaches

Country	Summarised approach
United Kingdom	There are three risk assessment tiers used in the United Kingdom: preliminary, generic quantitative and detailed quantitative risk assessment. During the preliminary risk assessment an initial conceptual model of the site is developed and potentially unacceptable risks are identified. In the generic quantitative risk assessment generic criteria are established and in order to be applied to actual or potential unacceptable risks. During the detailed quantitative risk assessment site-specific information is collected and remediation methods are applied.
Norway	The Norwegian risk assessment method is comprised of three tiers with increasing degree of complexity and detail. Tier 1 consists of a simplified risk assessment which is mainly based on the comparison of identified concentration of contaminants with soil quality guidelines. Tier 2 is an expanded risk assessment which introduces quality guidelines adjusted to current land use and takes into account specific soil conditions. Tier 3 represents an expanded risk assessment based on exposure measurements and acceptance criteria of receptors.
France	The risk assessment method in France implies two phases. The Simplified Risk Assessment is based on the information collected during the preliminary site investigation and is used to classify contaminated sites. The Detailed Risk Assessment aims at evaluating risk levels, in terms of land use planning. Based on the results of the Detailed Risk Assessment remediation measures are taken.
Germany	In Germany risk assessment can be divided in two phases. It is considered that a site suspected of being contaminated shall be subject to an exploratory investigation. If the suspicion is confirmed and contamination exists detailed investigation should be conducted and potential risks are established.
USA	Risk assessment in USA is seen in a particular form named “cumulative risk assessment”. The cumulative risk assessment approach is based on identifying combined risks to health or the environment from multiple agents or stressors. The assessment can be conducted in both a qualitative or quantitative matter.
Australia	A staged approach is recommended to be adopted in Australia. This should include a screening risk assessment, a simple risk assessment and a detailed risk assessment. The screening risk assessment aims at identifying the contamination issue while the simple risk assessment correlates the previous findings with data regarding exposure. The detailed risk assessment is carried out adding contaminant transport modelling and toxicity assessments of particular contaminants.
New Zealand	Risk assessment in New Zealand can be undertaken at three different levels. The first level is considered to be qualitative and assesses contaminants of concern against published assessment criteria. The second level is semi-quantitative and undertakes specific customisation with contaminate specific pathways, receptors, and environmental conditions. The third level is quantitative and involves complex models that calculate accurately risks posed by contaminants to specific receptors.

CONCLUSIONS

After conducting an overview of the methods used when assessing risks in United Kingdom, Norway, France, Germany, USA, Australia and New Zealand several aspects can be concluded. On one hand risk assessment is perceived in a similar manner by six of the seven policy makers analyzed. In six out of seven cases the process is divided into tiers or phases. Norway, Australia and New Zealand use three risk assessment tiers with increasing degree of complexity while in Germany and France the risk assessment method implies two phases, a simplified investigation and a detailed investigation. Nevertheless, USA has a completely different point of view on the matter. There, risk assessment is seen as a cumulative process and focuses on identifying combined risks. The analysis is conducted by taking into a particular discussion each agent or stressor that may pose risks for human health or the environment. A complete risk assessment image is assembled at the end.

On the other hand risk assessments in all countries analysed are achieved by evaluating a series of parameters. These can be grouped in the following categories: contaminant characteristics, receptor type and risk perception, exposure to contaminants, site conditions, transfer pathway and possibility of contamination extension and mechanism of pollution. By estimating their importance through analysing the frequency of their appearance in risk assessment methods it can be stated that contaminant characteristic and receptor type and risk perception are the key parameters that need to be taken into account in order to successfully undertake this process.

In conclusion, a harmonized integrated approach can theoretically be applied, but due to the insignificant differences between approaches there is no real need for such a measure.

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REFERENCES

BIANCO, A., NOBILE, C., GNISCI, F. (2008): Knowledge and perceptions of the health effects of environmental hazards in the general population in Italy. *International journal of Hygiene and Environmental health*, 211: 412-419.

DEPARTMENT OF ENVIRONMENT, GOVERNMENT OF WESTERN AUSTRALIA (2005): The use of Risk assessment in contaminated Site Assessment available at:

http://portal.environment.wa.gov.au/pls/portal/docs/PAGE/DOE_ADMIN/GUIDELINE_REPOSITORY/CONTSITES_RISKASS_100205.PDF

FEDERAL GERMAN GOVERNMENT (1999): Federal Soil Protection and Contaminated Sites Ordinance available at: http://www.bmu.de/fileadmin/bm-import/files/pdfs/allgemein/application/pdf/bbodschv_uk.pdf

FERGUSON, C., DARMANDRAI, D., FREIER, K., JENSEN, K., KASAMAS, H., URZELAI, A., VEGTER, V. (1998): Risk assessment for contaminated sites in Europe, LQM Press, http://www.commonforum.eu/Documents/DOC/Caracas/caracas_publ1.pdf

- HANSSON, S.O. (2007): Risk, Stanford Encyclopaedia of Philosophy (Summer 2007 Edition).
- MINISTRY OF ENVIRONMENT AND SUSTAINABLE DEVELOPMENT (2003): The French approach to contaminated-land management available at <http://www.brgm.fr/result/telechargement/telechargement.jsp?id=RSP-BRGM/RP-52276-FR>
- NATURAL LAND RESEARCH CENTRE (2007): Risk Assessment for Contaminated Sites in New Zealand available at <http://contamsites.landcareresearch.co.nz/>
- NORWEGIAN POLLUTION CONTROL AUTHORITY (1999): Guidelines for the Risk Assessment of Contaminated Sites, available at: <http://www.klif.no/publikasjoner/andre/1691/ta1691.pdf>
- U.S. Environmental Protection Agency (1994), Framework for Cumulative Risk Assessment available at: http://www.epa.gov/raf/publications/pdfs/frmwrk_cum_risk_assmnt.pdf
- UK ENVIRONMENTAL AGENCY (2004): Model Procedures for the Management of Land Contamination, available at <http://www.environment-agency.gov.uk/research/planning/.aspx>