CONTRACT NB SD/TE/02A

FRAC-WECO

Flux-based Risk Assessment of the impact of Contaminants

on Water resources and ECOsystems

Programme: La Science pour un Développement Durable

Programma: Wetenschap voor een Duurzame Ontwikkeling

Deliverable D2.5

Decision grid for best approach in terms of modelling concepts/contaminants

Responsible D.Caterina (ULg HG), Michael Haberman (ULg HG)

Contributors S. Brouyère, A.Dassargues

Corresponding authors: David.Caterina@ulg.ac.be, Tel: +32 4 366 92 62

Serge.Brouyere@ulg.ac.be, Tel: +32 4 366 23 77

Alain.Dassargues@ulg.ac.be, Tel: +32 4 366 23 76

Due date: April 2008

Contents

List of illustrations

List of tables

1. General context

For many years, Belgium as well as many other industrialised countries throughout the world (EU, USA, etc.), have become aware of problems related to contamination issues. Many industrial and economical activities are the main causes of the presence of contaminants in the environment, especially due to development of industries without environmental considerations or constraints. In fact, economical activities (industries, agriculture, etc.) emit a large quantity of toxic substances (chlorinated solvents, pesticides, etc.) in the environment and these compounds can therefore be found in the air, soil, surface water and groundwater. This general contamination may cause many damages on human health, ecosystems and natural resources.

According to the European Environment Agency (EEA, 2007), polluting activities have been carried out on 3 millions of sites in Europe during these last years, among which 1.8 million sites are now potentially contaminated. Until now, only 250 000 of them have been clearly identified but this number could increase in the future with new investigations.

The main sources of contamination may be listed as follows:

Potential sources of land contamination	
Industrial	gas works,coal processing,extractive industry, mines, chemical production or use, electroplating, timber reservation, metal production/manufacturing, chemical stores, pesticide formulation, food processing, pulp and paper manufacture, textile production, other industries
Commercial	petrol service stations, transport services/maintenance, motor car wrecking, waste, recycling depot/plant
Service sector	municipal/industrial landfills, sewage treatment works, fuel depots, energy generating plants, laboratories
Agricultural	intensive use of pesticides, aerial spraying operations, pesticide storehouses
Other	abandoned dumpsites, abandoned mines, factory or warehouse fire, chemical transport accident

Table 1 : Types of land contamination (adapted from UNEP & al., 2005)

Statistical data from EEA have listed the major pollutants found in soils, among which heavy metals (for 37.3% of cases) and hydrocarbons (33.7%) constitute the two main categories.

For the specific case of groundwater, hydrocarbons constitute the main types of pollutants, followed by chlorinated compounds. This study has also shown that 80 000 of industrial sites have been the subject of decontamination works these last 30 years. So, people have become more and more aware and informed of risks posed by these sites on the environment and have become conscious of the necessity to preserve and restore natural resources and ecosystems. Therefore, these sites have to be managed both from a risk and economical point of view.

To achieve these objectives, one needs:

- efficient methodologies and norms for screening contaminated sites with respect to contamination types and levels;
- a reliable evaluation of the possible impacts of these sites on the environment, by direct exposure or by dispersion in the environment, particularly through water resources;
- risk assessment for humans, ecosystems and natural resources and;
- the development of tools and methodologies for evaluating, ranking and optimizing remediation measures.

Despite the fact that many human and financial efforts have been devoted to these important objectives, one has to admit that there is nowadays no unified system allowing to hierarchise methodologies and tools for site screening, risk assessment and remediation optimization. There have been general accepted concepts and advanced research efforts but the topic is wide: many contexts, many contaminants and many “targets” and important research works still have to be performed.

One of the objectives of the FRAC-WECO project is to propose, develop and validate site screening and risk assessment tools. A first essential step is to provide a relatively detailed overview of existing methodologies and modelling tools for risk assessment. These tools should notably assess the appropriate information about fate and transport of contaminants from the pollutant source through groundwater (i.e. leaching to and transport in the aquifers) and their possible transformation during their travel allowing thereby assessing their possible effects and impacts on different receptors, i.e. ecosystems, water resources. Such a modelling approach may improve the reliability of the assessment in order to help in the decision making as well as in assessing the costs of a possible contaminated land remediation.

This deliverable constitutes a review of existing approaches for site screening and risk assessment methodologies and modelling tools. This review aims at identifying those that are the most appropriate with respect to the general philosophy of the FRAC-WECO project, i.e. flux-based risk assessment and the considered targets, i.e. water resources and associated ecosystems.

The document is organised as follows. First, the concepts of risk assessment are discussed and classical methodological frameworks are presented. Second, several methodologies for the management of contaminated megasites are described. Third, a synthesis of existing risk assessment tools is proposed based on a detailed literature review. Finally, a general discussion is proposed and conclusions are drawn in terms of research directions to be followed in FRAC-WECO.

2. Introduction to risk assessment concepts

2.1. Introduction

2.1.1 Definition

For few years, risk assessment has become a commonly used approach in environmental policy (regulators, industries, etc.) because it helps and facilitates decision making for the management of natural resources and the prevention of damages caused on ecosystems and human health. A widened knowledge of potential environmental stressors, by identification and quantification of risks associated with potential threats, and the collaboration of stakeholders are fundamental to insure the most appropriate decision. Although risk assessment is central in environmental policy and practice, it is not an easy or well-defined concept, due notably to different terminologies, approaches and conventional choices taken in each country or region.

Several definitions, ranging from informal to very formal (mathematical), were already mentioned by Vlek (1990) and many other authors.

Risk is usually defined as "the chance of disaster" but in the risk assessment process, it is defined as the combination of “the probability/frequency of occurrence of a defined hazard and the magnitude of consequences of the occurrence” (Royal Society of London, 1992). The risks caused by hazards are estimated either quantitatively or qualitatively. Risk is estimated by likelihood measures of the hazard actually causing harm and severity measures of harm in terms of impacts to people and environment (effects and threats of an agent on humans and ecosystems). Risk depends on both the level of toxicity of hazardous agents and on the level of exposure.

Environmental Risk Assessment (ERA) represents the global term including human health and ecological risks. ERA involves the examination of risks resulting from natural events (flooding, extreme weather events, etc.), technology, practices, processes, products, agents (chemical, biological, etc.) and industrial activities.

It is usually admit that a contaminated site poses a risk only if the following three conditions are met:

- a source of mobilisable contaminants;

- transfer pathways;
- existence of receptors.

These conditions correspond to the main elements of the Source – Pathway – Receptors Approach (SPR) which is described in detail for the FRAC-WECO project in deliverable *D12: Methodology for integration of process studies and development of a decisison support tool*.

If one of the three conditions is not met, the contaminated site does not pose an immediate risk.

2.1.2 Various types of risk assessment

Risk assessment is a relatively complex concept that is not only limited to the assessment of contaminated lands.

Indeed, it can be used for other purposes, varying from prevention of pollution by new chemicals to environmental and financial impacts assessment.

ERA can be used in a number of ways:

- *Prioritization of risks*: according to potential environmental risks, ERA can be used to establish their relative importance, and thus provides a basis for prioritizing which risks should be dealt with first;
- *Site-specific risk evaluation*: ERA can be used to determine the risks associated with a particular site (CSA, 1997);
- *Comparative risk assessment*: ERA can be used to compare the relative risks caused by stressors at different scales;
- *Quantification of risks*: ERA can be used to quantify the risks in order to establish appropriate controls and monitoring on these risks (i.e. maximum “acceptable” concentration).

According to the types of risks and the results of ERA, risks may be managed by elimination, transfer, retention or reduction to achieve an “acceptable” level of risk.

2.1.3 Limitations of risk assessment

Many organisations in Europe and throughout the world, are actively involved in environmental risk assessment, developing methodologies and techniques to improve environmental management tools. Nevertheless, this concept often tends to have a possible over-reliance in results and generally focuses on parts of a problem rather than on its whole. Moreover, in contaminated lands, risk assessment is usually not a preventive approach because the polluting source already exists.

The major difficulties in the use of risk assessment are data availability and uncertainties. These uncertainties may be listed according to many categories (Wynne, 1972; Shrader-Frechette, 1996):

- *Samples*: uncertainties related to measurements accuracy or samples validity;
- *Data*: interpolation or extrapolation of data;
- *Knowledge*: insufficient understanding of the topic;
- *Models*: approximation of the real environment;
- *Environment*: uncertainties related to the inherent variability of the environment causing errors in the contaminated lands characterization and;
- *Decision theoretic uncertainty*: doubt in the choice of decisions based on the type of risks, contemplated scenarios, cost/benefit analyses, etc.

Risks perception may also play a role in assessing and managing risks because it often depends on people attitudes and social or cultural values adopted towards hazards. The risk assessment depends widely on legislative aspects such as environmental standards, cost/benefit, industrial norms, government policy, etc.

So, it is fundamental to understand the level of uncertainty and to identify the weak points and limits of the risk assessment at each stage of the process.

2.2. Methodologies for risk assessment of contaminated sites

2.2.1 Introduction

Previously, methodologies used for the remediation of contaminated lands were little based on risks analysis and assessment. Rehabiliation costs were generally too high to "clean up" the polluted soils and the process was often dropped (Salt *et al.*, 1995).

For a few years, many countries have changed their policies with regards to remediation techniques. They tend now to focus more towards a land-use-based approach where risk assessment is an integrative part of the rehabilitation process (Ferguson *et al.*, 1998).

Furthermore, the type of contaminants, their toxicity, the potential receptors, the political and social context, are all many important criteria considered in the process. In this perspective, a Risk Based Land Management (RBLM) concept was developed to help decisions making for remediation of contaminated lands by assessing the risks and priorities, by considering the long term effects of contaminants on environment and by evaluating costs and benefits (Clarinet, 2002). This approach tends to reduce the rehabilitation costs by limiting the number of treatments applied to the polluted soils. Indeed, it allows to stop the cleaning process as soon as an "acceptable" level of contamination is achieved, the risks generated by the remaining part of contaminants being under control.

Different international approaches focusing on ecological risk assessment for land contamination are presented in Annex 2 (Smith *et al.*, 2005).

2.2.2 Components of risk assessment

Risk assessment of contaminated lands is often based on a causal stress-response model in which the pollutant is transported from a **S**ource through a known **P**athway to a **R**eceptor. This approach, commonly called *SPR*, constitutes the basis of risk assessment into which the FRAC-WECO project fits.

The risk assessment process generally consists of many phases or "tiers" in which different procedures or concepts are involved and studied. At each tier in the advancement of the process, the need of data grows, the costs become increasingly important while hoping to reduce the risks, the assumptions and the uncertainties related to the knowledge of the problem (Figure 1).

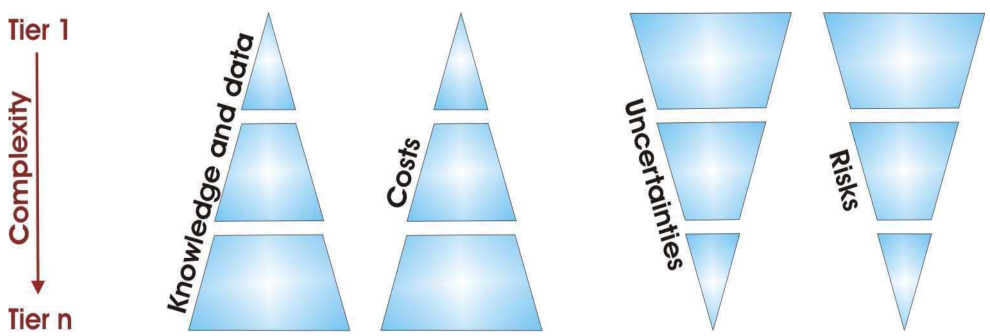


Figure 1 : Complexity level as regards with tiers of the risk assessment process

Risk assessment usually starts with some suspicions about the possible presence of pollutants in soils or groundwater. This qualitative information - *tier 1* - may lead initially to subjective assessment about environmental risks and sometimes financial risks for people potentially affected by the polluted sites (Ferguson *et al.*, 1998). In order to be more certain about the consequences of pollution, investigations may be carried out to establish contamination levels based on different criteria, i.e. type of contaminants, their toxicity, their concentrations, potential effects/impacts on environment, risks for human and ecosystems, etc. Pollutant concentrations measured in soils and groundwater are compared to predetermined guideline values or quality standards to evaluate whether it is necessary to carry on further investigations. If the concentrations of contaminants exceed guideline values, more detailed investigations are required - *tier 2*. In most countries, the use of these guidelines may serve as first screening of ecological risks (Ferguson *et al.*, 1998). At each new step in the advancement of the process - *tier n* -, the information becomes progressively more quantitative, through the development of complex models supported by new intensive investigations of the contaminants of concern, pathways and receptors characteristics, etc.

Each new investigation aims to increase the level of confidence in the results and conclusions by a better knowledge of the problem while reducing the risks and the associated uncertainties (Figure 1).

2.2.3 Framework of risk assessment

Although several frameworks for environmental risk assessment and management were developed throughout the world, most of them are nowadays based on the report "Risk Assessment in the Federal Government: Managing the Process," from the US National Research Council (NRC, 1983). Nevertheless, different criteria such as the political and social context may lead to differences between countries.

The generalised framework drawn for ERA includes five main steps as illustrated in Figure 2 (NRC, 1983; US EPA, 1998; R. Fairman *et al.*, 1999):

- <u>Problem formulation</u>: general description of the problem with delineation of goals and objectives. This step is the "foundation" in the process. It is the phase where risk assessment is defined and the planning for analyzing and characterizing risks is developed (US EPA 1992/1998). This step provides some information concerning current and historic land-uses, potential/actual contaminants of concern, potential pathways, potential receptors, areas of uncertainty. This information allows to describe the system briefly. It is the step where each element described in the SPR and DPSIR approaches (integrated in the FRAC-WECO project) are identified ;

- *Hazard identification*: identification of agents that may cause adverse effects. This step is often part of the problem formulation (i.e. US EPA), but it may be revisited during the characterization of effects if new data suggest additional hazards;
- *Exposure assessment (characterisation of exposure)*: estimation of concentrations, doses and degree of contact of the hazardous agents in question with the environment. Generally, this phase requires the identification, the characterisation and the quantification of all sources and stressors and use contaminants fate and transport models for evaluating the pathways and exposure in groundwater and surface water (relationship between the contaminants source and the potential pathways, i.e. groundwater, as mentioned in the SPR approach of the present project);
- *Dose-response assessment (characterisation of effects)*: estimation of the relationship between exposure (or dose) to a stressor and the incident and severity of an effect on the environment. This step requires the evaluation of the nature, intensity and time scale of adverse effects with a causal relation to the stressor and the identification of modes of action;
- *Risk characterisation*: evaluation and conclusions. The objective of this step is to collate and summarise the information obtained during the previous tasks in order to determine the probability that a risk exists,and its potential magnitude, and to provide the adequate decisions for risk management. Risk characterisation involves comparing on-site contaminant concentrations with guideline values (relationship between the pollutants source and impacts on ecosystems and water resources through the DPSIR approach).

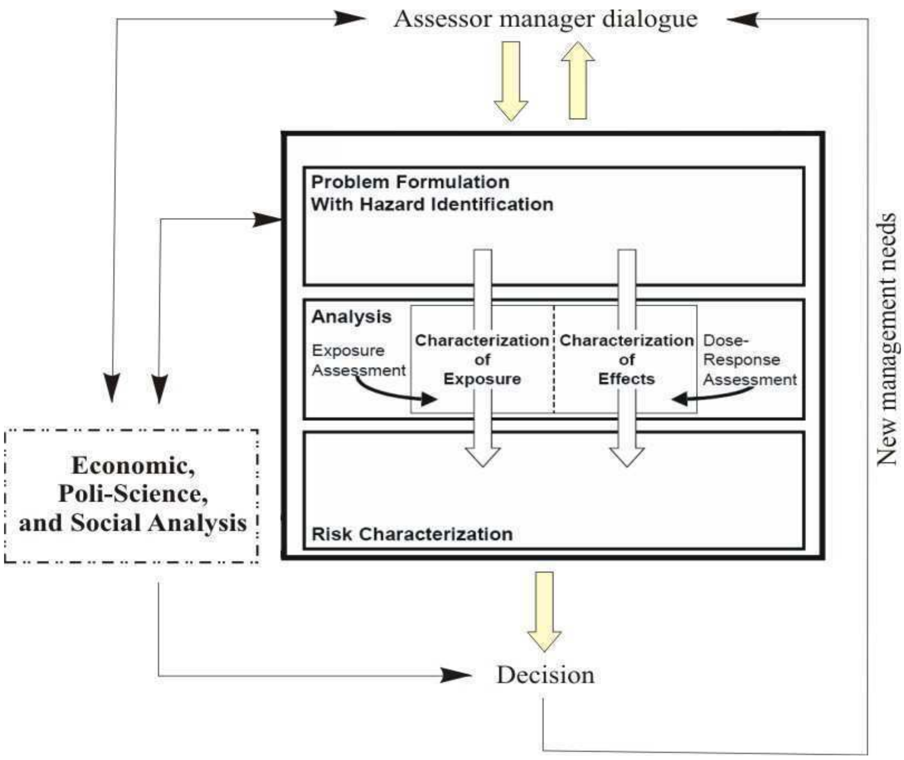


Figure 2 : Framework of risk assessment (adapted from US EPA, 1998)

The risk assessment process is often divided into three main levels (Figure 2). The problem formulation with hazard identification is generally considered as tier 1. With the analysis for characterization of exposure and effects, complex modelling tools are necessary to assess accurately the damages on environment and the risks. This second step is generally the tier 2. Finally, the tier 3 includes the conclusions of the risk assessment process with risk characterization in order to help the decision making for a possible contaminated lands rehabilitation. Each stage in the procedure may be iterated if additional data or analysis is needed to support the risk management process.

In some countries (notably in UK or New Zeland), risk assessment can be subdivided into three distinct tiers in which the five key tasks of risk assessment are undertaken. Gathered information and data are then used to support the risk management decision and to decide whether it is necessary to proceed to the next tier. In other countries (notably in USA), risk assessment methods do not explicitly provide a tiered approach but leave the decision to risk assessors.

If well designed, a tiered approach provides a systematic way of determining what level of investigation is appropriate for the site of concern, minimizing the number of unnecessary investigations and allowing a more efficient use of resources. At each tier, if the contaminant concentrations do not exceed the threshold values, the risk assessment process may be suspended without proceeding to the next step.

2.2.4 Screening and guideline values

Nowadays, risk assessment is a widely accepted procedure in contaminated land policies to classify polluted soils. This classification is based on threshold concentration values, commonly called *screening and guideline values* (S/G values). *Screening values* are intended to screen out sites (or parts of sites) for which risks are considered as being too small to warrant more detailed investigation. They are generally based on pessimistic exposure assumptions or rigorous criteria for maximum tolerable risk. *Guideline values* are used by risk assessors as generic guidance to provide information on the significance of contaminant concentrations in soil, groundwater or other media. They may be based on rigorous multi-pathway probabilistic risk analysis of generic exposure scenarios or on the most basic screening values..

Although the S/G values are recognized throughout the world, there are some differences between countries with regards to their roles and definitions. According to the different phases in the risk assessment and management of contaminated sites (investigations and decision making process), S/G values may be generally classified as follows (Figure 3):

- *Background values* (**R0**): reference level corresponding to unpolluted or non-anthropogenic conditions. Risks are considered as negligible;
- *"Conservative" values* (**R1**): level below which the risk is considered as acceptable. Above this value, significative risks are more likely to occur and some new considerations and risk assessment may be required;
- *"Realistic" values* (**R2**): for concentrations above these values, the existence of unacceptable risks is strongly presumed and further investigations are necessary;
- *Action/Intervention values* (**R3**): generic values based on acute risks to sensitive receptors. The measured contaminants concentrations exceed the intervention values, meaning unacceptable harm or damage. The site remediation becomes a priority.

In general, the R0-type values are established, predicated on "natural" background noise, as for the R1, R2 and R3-type values, they are calculated by taking into account risks for human health, ecosystems, etc. In the specific case of groundwater, the R0-type values provide a value of background concentrations in pollutant without natural geochemical background and economical activities (agriculture, industries, etc.). R1, R2 and R3-type values are calculated from ecotoxicological data by evaluating the response of a known pollutant agent on a defined ecosystem.

The four above-mentioned values may have many functionalities:

- The R0-type values allow differentiating natural and anthropogenic concentrations;
- The R1 and R2-type values inform on the need to perform further investigations and more detailed risk assessment;
- The R2 and R3-type values are usually used to establish the need for remediation;

In some countries, S/G values may be used as remediation objectives when the remedial technologies are available at a reasonable cost. In this case, the R0-type values may help to identify remediation targets constituting negligible risks; the R1 and R2-type values may classify remediation targets on the basis of acceptable risks related to land-use.

In general, three different approaches can be distinguished in the site assessment process according to countries (Figure 3):

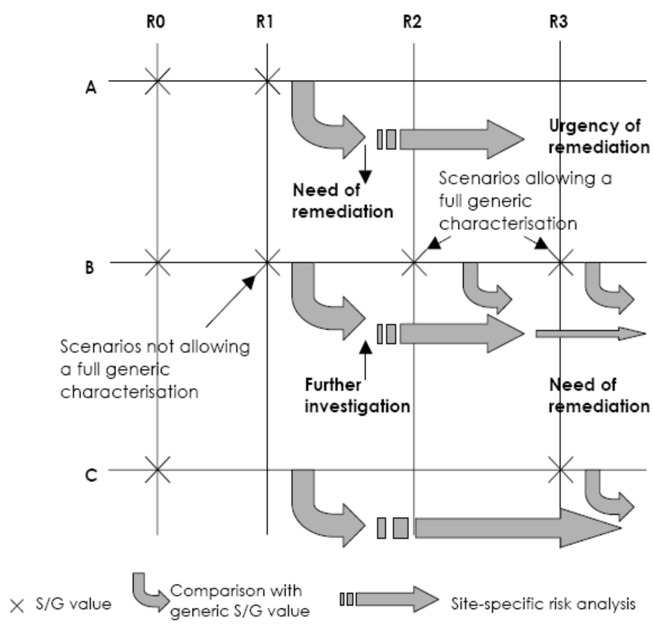


Figure 3 : Graphical representation of generic value types (R0, R1, R2, R3) and approaches taken in different countries (Ferguson *et al.*, 1998)

- *Type A*: based on guideline values (i.e. Denmark, the Netherlands or Italy);

- *Type B*: based on screening values for a simplified risk assessment (i.e. Austria, Flanders, Finland, France, Germany, Norway and Switzerland);
- *Type C*: generally based on guideline values, this approach depends strongly on characteristics of the investigated site and so, it is fundamental to verify the appropriateness of considered values before beginning the risk assessment process (i.e. Greece, Portugal, Sweden and the United Kingdom).

The S/G values may be refered to the soil medium, to groundwater and in a few cases, to surface water and air. They may also be influenced by the origin of contaminated site (agricultural or industrial activities), the type of contamination (metals, organic compounds, etc.), the type of receptors (human, ecosystems, etc.).

As shown in Table 2, most countries are using or intending to use S/G values in the context of their policies on contaminated lands.

Country	S/G values	Nomenclature	Comments
Austria (A)	Yes	Screening values (a,e)	Published
		Action values (a,e)	Published
Belgium (B)			
Flanders	Yes	Remediation values (s,g)	Published/in prep.
	Yes	Background values (s,g)	Published
Wallonia	Intended		
Brussels	Intended		
Denmark (DK)	Yes	Quality Criteria (s,g)	Published
		Background values (s,g)	Published
Finland (FIN)	Yes	Target values (s,g)	Dutch values
		Limit values	In prep.
		Background values (s,g)	Published
France (FR)	Yes	VCI (Impact Assessment Value) (s,g)	In prep.
		VDS (Source Definition Value)	In prep.
Germany (D)	Yes	Trigger values (s)	Published/in prep.
		Action values (s)	Published/in prep.
		Background values (s,g)	Published
Baden-Württemberg	Yes	Background & assessment values (H-P) (s)	Published
Bavary	Yes	Soil values (SV) I, II, III (s)	Published
Berlin	Yes	Action & Reutilisation values	Published
Hambourg	Yes	Remediation values (s,g)	Published
Nordrhein-Westfalen	Yes	Limit values (s)	Published
Saxony	Yes	Assessment & clean-up values (s)	Published
Greece (GR)	Yes	Water Guideline values (w)	Int. stand. too
Ireland (IR)	Not int.		
Italy (IT)	Yes	Acceptable levels	In prep.
Piemonte	Yes	Acceptable/Remediation Levels	Int. stand.
Toscana	Yes	Acceptable/Remediation Levels	Int. stand.
Lombardia	Yes	Acceptable/Remediation Levels	Int. stand.
Emilia Romagna	Yes	Acceptable/Remediation Levels	Int. stand.
Netherlands (NL)	Yes	Intervention values (s,g)	Published
		Target values (s,g)	Published
Norway (N)	Yes	Threshold values (s)	Danish/Dutch values
Portugal (P)	Yes	Remediation values	Canadian values
Spain (SP)	Intended		
Basque Country	Yes	B-assessment values (s)	Published/in prep.
		C-assessment values (s)	Published/in prep.
		A-assessment values (s)	Published
Sweden (SW)	Yes	Generic soil guideline values (s)	Published
Switzerland (CH)	Yes	Trigger values (s)	Published/in prep.
		Clean-up values (s,e,a)	Published/in prep.
		Guideline values (s)	Published/in prep.
United Kingdom (UK)	Yes	Guideline values (s)	In prep.
		Trigger threshold values (old) (s)	Published
		Trigger action values (old) (s)	Published
Australia (AUS)	Yes	Investigation levels (s)	
		Background levels	
Canada (CAN) CCME	Yes	Assessment values (s,w/g)	Published
		Remediation values (s,w/g)	Published
Alberta	Yes	Tier I criteria (s)	Published
British Columbia	Yes	Reference and action values (s,w/g)	Published
Ontario	Yes	Clean-up criteria (s)	Published
Quebec	Yes	A,B,C values (s,g)	Published
USA	Yes	Soil Screening Levels (s)	Published
		MCLS (w/g)	Published

s: soil; g: groundwater; w: surface water; a: soil air; e: eluate

Table 2 : S/G values within the soil policy framework in different countries (Ferguson *et al.*, 1998)

2.3. Methodologies for risk assessment of contaminated megasites

2.3.1 Introduction

The economic analysis developed in the WP5 raised several questions among which: What is the relevant spatial scale for the project? Indeed, groundwater degradation is rarely related to only one specific source of pollution. In these conditions, it is difficult to prove that a pollution is due to one site rather than another especially if the site is located in a heavily industrialized area. This is why it would be interesting in the scope of the FRAC-WECO project to work on a larger scale than the one of a single site. The *megasite scale* could be used.

A megasite is defined as "a large area (indicative size: 5 - 500 km2) with multiple contaminant sources related to (former) industrial activities, with a significant impact on the environment, through groundwater, surface water and/or air migration. Due to its complexity related to site conditions, contaminant characteristics, organization, regulatory aspects and/or considerable costs, an integrated risk-based management approach is recommended to manage the risks for the defined receptors" (WELCOME EU project) .

It has been estimated that megasites represent 30 to 50 % of costs associated with the remediation of contaminated soils and water in Europe. Remediation costs for such sites amount several billions of euros (WELCOME, 2002).

The complete depollution of contaminated megasites is not an economically and technically viable solution because of their large extent. An alternative is an approach based on the management of risk which allows to achieve risks compatible with the use of the site while maintaining realistic pollution control costs (Béranger and al., 2006).

The management of contaminated megasites has been subject of several studies and national methodologies. At the European level, projects such as WELCOME and INCORE have proposed methodologies for the management of contaminated megasites. In the next sections, these two projects will be described as well as the american point of view with the Superfund program.

2.3.2 *Superfund*

Superfund is an environmental program developed in the U.S. during the 80's. It is addressed to industrial contaminated megasites.

The Superfund cleanup process may be divided into 9 main steps (US EPA, 2007):

1. Preliminary Assessment (PA)/ Site inspection (SI)

PA consists in collecting available information about a site and determining whether it poses little or no threat to human health and to the environment. If the PA results in a recommendation for further investigation, a Site Inspection is performed. SI studies the nature of the contaminants and determines if they can be released to the environment and if they have reached nearby receptors. Based on these results, the site is entered in the NPL Site Listing Process.

2. National Priorities List (NPL) Site Listing Process

The NPL is the list of U.S. priorities among the known releases or threatened releases of hazardous substances, pollutants, or contaminants throughout the U.S. and their territories.

3. Remedial investigation (RI)/ Feasability Study (FS)

The remedial investigation/ Feasability Study includes the following steps:

a. Scoping activities

They begin with the collection of existing site data, including data from previous investigations. The objectives are to:

- firstly identify boundaries of the study area;
- identify likely remedial action objectives;
- establish whether the site may best be remedied as one or several separate operable units.

b. Site Characterization

During this phase, samples are taken on field and analysed in laboratory. A baseline risk assessment is developed to identify the existing or potential risks that may be posed to human health and to the environment by the site.

c. Development and Screening Alternatives

The objectives of this step are;

- identifying remedial action objectives;
- identifying potential treatment, resource recovery, and containment technologies that will satisfy these objectives;
- screening the technologies based on their effectiveness, implementability, and cost;
- alternatives can be developed to address contaminated medium, a specific area of the site, or the entire site.

Once potential alternatives have been developed, it may be necessary to screen out certain options to reduce the number of alternatives that will be analyzed. The screening process involves evaluating alternatives with respect to their effectiveness, implementability and cost.

d. Treatability Investigations

Treatability investigations are conducted primarily to:

- provide sufficient data to allow treatment alternatives to be fully developed and evaluated during the detailed analysis phase and to support the remedial design of selected alternatives;
- reduce cost and performance uncertainties for treatment alternatives to acceptable levels so that a remedy can be selected.

e. Detailed Analysis

Once sufficient data are available, alternatives are evaluated in detail with respect to evaluation criteria. The criteria include:

- overall protection of human health and environment;
- long-term effectiveness and permanence;
- reduction of toxicity, mobility, or volume;
- short-term effectiveness;
- implementability;
- cost;

- State acceptance; and
- community acceptance.

The alternatives are analyzed individually against each criterion and then compared against one another to determine their respective strengths and weaknesses. The results of the detailed analysis are summarized so that an appropriate remedy can be selected.

4. Records of Decision (ROD)

The Record of Decision is a public document that explains which cleanup alternatives will be used to clean up a Superfund site.

5. Remedial Design/ Remedial Action

Remedial Design (RD) is the phase in Superfund site cleanup where the technical specifications for cleanup remedies and technologies are designed

6. Construction Completion

EPA has developed the construction completions list (CCL) to simplify its system of categorizing sites and to better communicate the successful completion of cleanup activities

7. Post Construction Completion (PCC)

PCC is to ensure that Superfund response actions provide for the long-term protection of human health and of the environment. EPA's Post Construction Completion activities also involve optimizing remedies to increase effectiveness and/or reduce cost without sacrificing long-term protection of human health and of the environment.

8. National Priorities List Deletion

EPA may delete a final NPL site if it determines that no further response is required to protect human health or the environment.

9. Site Reuse/ Redevelopment

EPA’s goal is to make sure that at every cleanup site, the Agency and its partners have an effective process and the necessary tools and information needed to fully explore future uses, before the cleanup remedy is implemented.

More information is avalaible at: http://www.epa.gov/superfund/

2.3.3 INCORE (INtegrated COncept for groundwater REmediation)

The following paragraphs are taken from the website of the INCORE project: http://umweltwirtschaft-uw.de/incore/

The purpose of this project is to propose a cost-efficient technical-administrative set of tools to optimize investigation, evaluation and management of contaminated lands in urban industrial areas. The proposed INCORE strategy for the investigation, remediation and revitalisation of industrial areas is based on an integrated quantification of total contaminant emissions. It considers entire industrial areas instead of particular single sites, in order to achieve a high level of confidence in the investigation results.

The program is divided into three steps: investigation, assessment and revitalisation. It begins with the study of the pollution at the megasite scale and ends with the remediation of individual sources areas or with the containment of plumes. The main advantage of this approach is that the size of the studied areas decreases stepwise from one cycle to another (see figure 4).

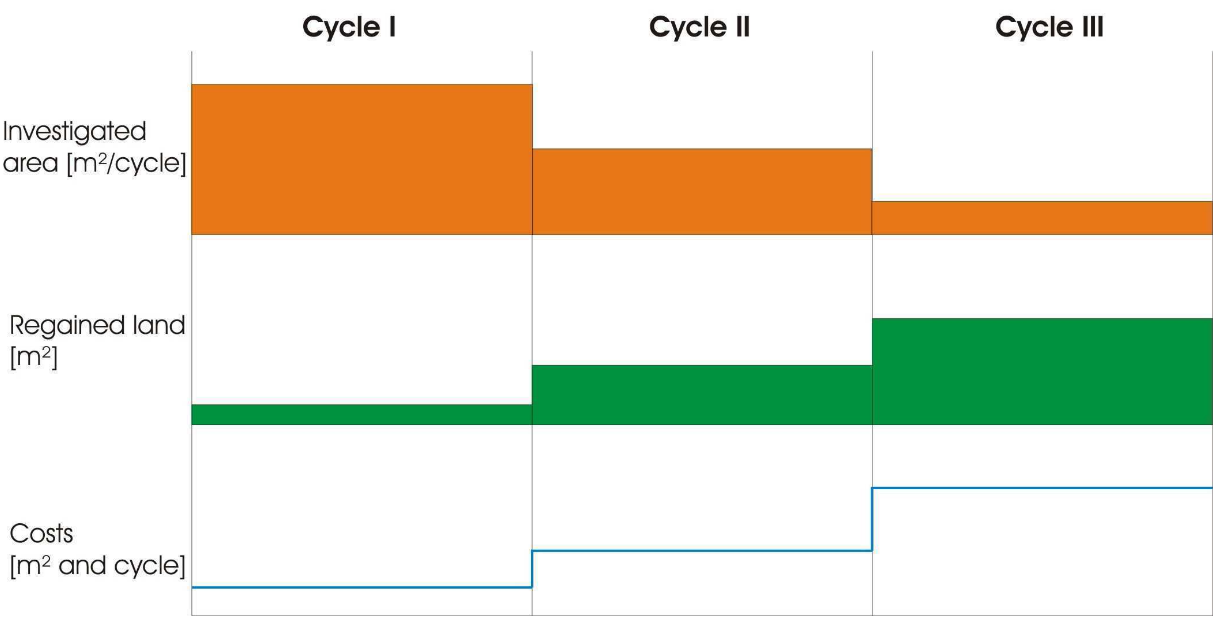


Figure 4 : INCORE cyclic approach (adapted from INCORE, 2003)

As shown in figure 4, the whole process can be divided in three cycles:

<u>Cycle I: Plume screening</u>

The first step is the gathering of historical data that will allow to define a conceptual model (= a functional description of the problem). This model will be used to design and perform

Integral Pumping Tests, IPTs (Teutsch and al., 2000). The purpose of the IPTs is to provide quantitative data about pollution for Cycle II (size of the area affected by contaminated groundwater and the number and position of potentially contaminated spots).

Cycle II: Source screening

The first objective of cycle II is the identification of the size of the sources with dynamic investigation using on-site analysis. Then, detailed fingerprinting studies in soil and groundwater using biomarkers and stable isotopes are used to clarifiy which contaminant sources are responsible for the identified plumes. The final objective of cycle II is to take administrative decision on the need for future remediation for each source zone identified.

Cycle III: Source/plume remediation

A feasibility study is firstly performed for site-specific remediation options. It comprises the evaluation of options for remediation of the source, the plume and integral or combined source-plume solutions. The most appropriate technology is selected by establishing what level of contamination reduction is required, considering the future purpose of the site as well as the profitability of each solution. Finally, the concept of RBLM (Risk Based Land Management), developed in the scope of the CLARINET project, is used to define the final rehabilitation scenario.

A detailed flow chart of the INCORE project can be found in annex 3.

*2.3.4 WELCOME (*Water, Environment and Landscape management at COntaminated MEgasites)

The following information is taken from the website of the WELCOME project: http://www.euwelcome.nl/kims/index.php

The WELCOME project was funded by the European Union and was executed from 2002 to 2004. The goal of the project was to develop an Integrated Management Strategy (IMS) for prevention and reduction of risks at contaminated industrial megasites. This IMS is a stepwise approach that takes the present situation as a starting point. A risk assessment that takes the soil-water system and the technical and economic feasilibity of the remediation actions into account forms the core of this methodology.

The IMS may be divided into 4 main steps: Starting IMS, Risk Assessment, Risk Management Scenarios, and Implementation.

Starting IMS

The main objective of this section is to provide all criteria needed to define a site as a megasite and to derive the specific management task.

- decide if the site is a megasite, and if the IMS could be suggested as an appropriate approach;
- form a group of stakeholders;
- make an overview of boundary conditions;
- make an inventory of megasite information;
- build a conceptual model. Including hypothesis on megasite boundaries and the risk management zone.

Risk assessment

To assess the risks associated to large-scale groundwater contamination, the IMS provides 5 steps:

- carry out a megasite characterization. This characterization is based on the conceptual model. It consists in collecting needed data to determine: the contaminant situation, the megasite natural systems and infrastructure, and the potential receptors;
- define potential risk clusters. A risk-cluster is a geographical subdivision of the risk management zone with source-pathway-receptor sequences that can be grouped together into one unit for which risks can be quantified and risk management scenarios can be developed. Risk clusters form the units on which the megasite risk management plan will be based;
- carry out fate and transport modelling. It is used for each derived cluster and each potential receptor to obtain information about the tendency of the temporal and spatial behaviour of contaminants. The output of this step is detailed determination and characterization of the contaminants pathways from diverse sources to the receptors within the defined clusters
- determine risks. Two approaches to assess risks are presented:
    - Preliminary assessment of current risks. This procedure is used when a complete fate and transport modelling is not completed due to e.g. lack of data.

- Comprehensive assessment of current and future risks. This procedure uses the fate and transport modelling. Based on the modelling results, the receptors at risk are identified: the emission is quantified in a mass flux predicted to enter - or a concentration to arrive at -the receptor.

Measured or modelled concentrations need to be compared to receptor specific-national or European standards. Exceeding values can be assessed as functions of time and space, and thus risk can be quantified and visualized for each risk cluster.

Site-specific standards are to be derived as a result of the risk assessment, depending on the following aspects:

- the functions of the receptors of concern
- the potential management scenarios (on a strategic level)
- the stakeholders' priority and risk perception

The standards determined for the receptors of concern serve as the input data for developing and optimising risk reduction scenarios

- Finalize clustering. The boundaries of the risk management zone are eventually readjusted according to the results of the risk assessment. After the approval of stakeholders the evaluation and selection of the risk reduction measures at a cluster level should be carried out.

Risk Management Scenarios

The objective of this step is to define management scenarios for the megasite that are cost-effective and sustainable. To achieve it, the following activities need to be done:

- Define the feasibility of management scenario for each cluster. The local situation and characteristics of the contamination determine whether or not techniques can be applied in practice.
- Perform cost-efficiency and risk reduction analysis. Scenarios have to be defined in which it is specified which measures are taken, when, where and to what extent they affect the contamination (effectiveness). The effectiveness of the scenarios is determined by risk reduction and costs.
- The stakeholders decide on a final scenario for the entire megasite.

Implementation

The final scenario chosen in the previous step need to be implemented, monitored and reviewed. The monitoring tends to control the performance of the management scenario. In the medium and long-term, the performances need to be reviewed and the scenario could eventually be upgraded if some changes in the system occur.

The WELCOME project provides a set of tools to help the user in the different steps of the process described above. The interested reader will find the list of these tools in annex 4 and more information on the website: http://www.euwelcome.nl/kims/tools/index.php

2.3.5 Which megasite approach for FRACO-WECO?

The European approaches briefly described above have advantages and disadvantages.

The approach outlined in the INCORE project offers a way to address the problematic of major polluted sites by progressively reducing the study area as the process advances. Conversely, the project does not sufficiently take into account the views of stakeholders. In addition, the concept of sustainable development is only integrated at the last step of the approach at the establishment of the RBLM (Béranger and al., 2006).

The approach outlined in the WELCOME project is based on the risk assessment as for the FRAC-WECO project. The process divided in four steps is clear. Each of them has a specific objective which allows to choose the adequate final scenario for the remediation of the megasite. In addition, the information or data collected during the whole project are easily integrable thanks to the cyclic process of the approach. There are however few points that should need to be more detailed: the integration of GIS tools, the communications with the stakeholders and the uncertainty inherent at the different stages of the process are poorly defined.

Initially, the FRAC-WECO project did not address to the problematic of contaminated megasites, focusing more on the risks associated with "local" contaminated sites. However, works performed in WP5, raised the following questions: how to assess specific damages to groundwater due to one contaminated site or benefits related to its cleanup if the site is part of an heavily industrial region (pollution plumes migrate within an aquifer and can mix each other)? If damages arise due to surface water degradation in relation with groundwater contamination by brownfields, how to assess specific damages due to surface water degradation related with one specific contaminated site? In summary, from the local site to the groundwater body level: what is the best scale for an economic analysis as part of FRAC-WECO project?

The selected test sites (Vilvoorde site[1], Chimeuse site and Morlanwelz site[2]) belong to industrialized areas making them far from being the unique potential source of groundwater contamination. WP5 emphasizes that the best scale to perform the socio-economic analysis on these sites is the water body scale. However, the resources allocated to the FRAC-WECO project do not allow to work at the water body scale using a megasite approach such as those described in the previous sections.

A "megasite" approach that could be used in the project would consist in estimating the part of the groundwater/surface water pollution due to a contaminated site compared to the whole groundwater/surface water pollution of the water body. This part can be expressed practically by a "weight" in any weighted statistics about the groundwater/surface water body.

---

[1] More exactly the « Vilvoorde-Mechelen area» located near the Zenne river (among others)

[2] More exactly the 'Nouveaux Ateliers Mécaniques' site located in Morlanwelz city (among others)

3. Synthesis of risk assessment tools

3.1. Introduction

The rehabilitation of contaminated sites is a complex process encompassing technological, environmental and socio-economic aspects. Several billions Euros are spent each year for remediation of lands affected by contamination. To limit the problems and costs related to the management of polluted lands, new tools, the *Decision Support Tools* (DST), have been widely developed these last years to help the decision-making.

DSTs are interactive softwares used by decision-makers to help answer to questions, solve problems and support or refute conclusions. They can be incorporated into a structured decision-making process to identify the choices of management of contaminated sites from a realistic point of view for environmental site cleanup. DSTs facilitate the use of data, models and structured decision processes in decision-making.

In the specific case of the FRAC-WECO project, integration of risk analysis models (for ecosystems and water resources) with socio-economic evaluations is fundamental to determine the most appropriate decisional process. DSTs have as purpose to define the different alternatives of effective rehabilitation interventions and efficient remediation actions, by representing the different decisional scenarios in the modelling tools.

3.2. Literature review of Decision Support Tools

It was estimated in 1999 that there were already more than 500 existing models (risk assessment/risk management models, exposure assessment/transport/fate models, hazard identificiation/release assessment models) throughout the world (Fairman & al., 1999). Nowadays, this number is probably higher than in 1999. Thus, a complete overview of all these models is an almost impossible task. Therefore, a first selection based on the most cited models in the literature was performed. In a second step, about thirty softwares were chosen according to their characteristics and their potential usefulness in the scope of the project. The criteria that were taken into account in the selection of the softwares are:

- the type of risk concerned (risk on water resources and ecosystems = ecological risk);

- the type of contaminants managed by the software (at least the most common ones: hydrocarbons, heavy metals, chlorinated solvents and semi-organic volatile compounds...);
- the type of media managed by the software (soil, groundwater and surface water);
- the possibility to take into account in a certain way the contaminant fluxes data (hydraulic conductivity, hydraulic gradient, ...);
- the possibility to take into account attenuation factors (partitioning between the liquid-, solid- and gaseous phases; re-distribution in the soil profile by sorption; dilution in groundwater; biodegradation);
- the complexity of the models (analytical or numerical);
- the possibility to use GIS data;
- the type of inputs and outputs;
- the possibility to calculate uncertainty on the results;
- the possibility to calculate cost-benefit from remedial action.

Fact sheets on the chosen decision support and modelling tools (DSTs) are presented in Annex 3 and summarized in Table 3. The information that can be found in Annex 3 mainly comes from references mentioned in the fact sheets and from the following websites:

- "Federal Remediation Technologies Roundtable" (FRTR): http://www.frtr.gov/decisionsupport/
- "European Environmental Agency" (EEA):

  http://reports.eea.europa.eu/GH-07-97-595-EN-C2/en/iss3c1h.html
- "Risk Assessment for Contaminated Sites in New Zealand" : http://contamsites.landcareresearch.co.nz/description_of_models.htm

Unfortunately none of the tools presented in Annex 3 meet all the criteria required in the scope of the project. Though, some of them seem to be more interesting and need to be studied more in details as shown in Table 3. These are: DESYRE, FIELDS, RBCA, RISC WORKBENCH and SADA.

Criteria / *Softwares*	Ecology I/R	Contaminants	Media	Transport data	Attenuation Factors	GIS	Uncertainty	Exposure effect	Input: Concentration	Input: Soil Properties	Cost/ Benefit
ABC-TOOL	Red	Green	Green	Red	Red	Red	Red	Red	Red	Yellow	Green
ARAMS	Green	Green	Green	Green	Red	Yellow	Green	Green	Green	Red	Red
CAMEO	Red	Green	Green	Red	Green	Green	Red	Red	Green	Green	Red
Chemflo 2000	Red	Green	Yellow	Green	Red	Red	Red	Red	Green	Green	Red
DESYRE	Yellow	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green
FIELDS	Green	Green	Green	Green	Red	Green	Yellow	Green	Green	Green	Green
GeoSEM	Green	Green	Green	Green	?	Green	Green	Green	Green	Red	Red
Groundwater Sensitivity Toolkit	Yellow	Yellow	Yellow	Green	Red	Red	Red	Red	Green	Green	Red
GroundwaterFX	Red	?	Yellow	Green	Green	Green	Green	Red	Green	Green	Red
HSSM	Red	Yellow	Yellow	Green	Green	Red	Red	Red	Green	Green	Red
MassFlux Toolkit	Red	Green	Yellow	Green	Green	Red	Green	Yellow	Green	Green	Red
NAS	Red	Green	Yellow	Green	Green	Red	Red	Red	Green	Green	Red
ON SITE	Red	Green	Green	Green	Green	Red	Green	Yellow	Green	Green	Red
PRO UCL	Red	Green	Green	Red	Red	Red	Yellow	Green	Green	Red	Red
RAT	Red	Green	Yellow	Red	Red	Yellow	Green	Red	Green	Red	Red
RBCA	Green	Green	Green	Green	Green	Yellow	Green	Green	Green	Green	?
RESRAD	Green	Red	Green	Green	Red	Red	Green	Green	Green	Green	Green
RISC WORKBENCH	Green	Green	Green	Green	Green	Red	Green	Green	Green	Green	?
SADA	Green	Green	Green	Green	Yellow	Green	Green	Green	Green	Green	Green
SCRIBE	Red	Green	Green	Red	Red	Red	?	Red	Red	Red	Red
SERDP	Red	Yellow	Yellow	Red	Green	Red	Red	Red	Yellow	Yellow	Red
SMARTe	Red	Green	Green	Green	Green	Red	Green	Red	Green	Red	Green
SOURCE DK	Red	Green	Yellow	Green	Green	Red	Green	Red	Green	Green	Red
VSP	Red	Green	Green	Red	Red	Green	Green	Red	Green	Red	Green

Table 3 : Summary of DSTs

Legend:

Green	Meet the criteria
Red	Do not meet the criteria
Yellow	Partially meet the criteria
?	Unknown information

3.3. Groundwater modelling

The DSTs described above may be used directly with field data. Though it is sometimes necessary to have a better understanding of the hydrogeologic conditions of the contaminated site before using DSTs. This is the reason why more elaborated models allowing to simulate more precisely groundwater flows and transport of dissolved contaminants will also be used in the RA process.

The suggested way to proceed with all these tools is the following one :

i. a first RA of the contaminated site using DSTs with avalaible data. This first step would tend to provide adequate information on the potential risk of the site on ecosystems and water ressources ;

ii. if it turns out that the site presents a risk for ecosystems and water resources, then it would be necessary to proceed to the modelling of the groundwater system ;

iii. the results of the groundwater modelling will be used as inputs for new RA simulations with DSTs.

Three groundwater models have been selected for the project. They must have the ability to simulate groundwater flows and transport of contaminants in three dimension.

Those models are :

- **SUFT3D**, developed by ULg-HG, is a 3D numerical model using finite elements and it allows the modelling of variably saturated groundwater flow and transport (including adsorption–desorption introduced by a delay factor) from local scale to catchment scale. In the SUFT3D, it is possible to model flow and transport using various mathematical approaches with different complexity levels: from a simple linear reservoir to a detailed spatially distributed approach.
- **HydroGeoSPhere,** developed by two research groups (University of Laval and University of Waterloo) under the coordination of Prof. R.Therrien. It is a fully coupled 3D flow and transport model using advanced numerical finite element algorithms. These models are currently developed to model specific contaminant reactions and retardation processes.
- **MODFLOW, MODPATH, MT3DMS (MT3D Multi Species)** and **RT3D** via the interface of **GMS** (Groundwater Modeling System developed by Environmental Modelling Research Laboratory). MODFLOW (McDonald & Harbaugh, 1984) is an

extremely versatile finite-difference groundwater flow model. MODPATH (Pollock, 1989) is a particle-tracking model that works with MODFLOW to calculate groundwater velocities, flow path lines, and advective travel times. MT3D (Zheng, 1990) also works with MODFLOW and calculates concentrations of groundwater contaminants. It simulates advection, retardation, dispersion, and decay (Fetter, 2001) . RT3D is a software package for simulating three-dimensional, multispecies, reactive transport in groundwater.

4. Conclusions and Recommandations

Nowadays, risk assessment (RA) process has become an integrating part in contaminated lands and natural resources management. This process is based on a causal stress-response model, commonly called the SPR approach, in which the polluting agent is considered from a source to a receptor through a known pathway. If one of the main elements of the SPR approach is missing, the contaminated site does not pose any immediate risk.

The process of risk assessment has however some limitations: the data availability and the uncertainties on samples, data, models, etc. That is why the process of RA is usually composed of several steps called tiers. More advanced is the process, larger is the need of data and more important are the costs. Nevertheless, each new tier leads to a reduction of uncertainties.

Currently, there are no universal methodologies and tools for site screening and risk assessment, due to specificities of each site and situation as well as political, social and environmental contexts of each country or region. However, many countries have based their environmental policy on the U.S. one which includes five main steps: problem formulation, hazard identification, characterization of exposure, dose- response and risk characterization.

In industrialized areas, it is sometimes difficult to attribute the observed pollution to a single site as there are lots of pollution sources. It is therefore interesting to consider the contaminated area as a whole, what is called the “megasite”. Several management methodologies of contaminated megasites have been reviewed in this deliverable. For the FRAC-WECO project, it is suggested (WP5) to work at the water body scale to perform the socio-economic analysis. At this scale and with the avalaibe resources, the project will tend to estimate the relative weight of the groundwater/surface water pollution due to a contaminated site compared to the whole groundwater/surface water pollution of the water body.

Among the objectives of the FRAC-WECO project, the development and the validation of site screening and risk assessment tools are key steps. In this perspective, an important review of risk assessment and modelling tools used as decision support has been performed. First, the most cited in the literature have been selected and then classified in terms of general criteria such as: type of risk concerned, type of contaminants, parameters to introduce/input, calculation of uncertainty, etc. This classification allows therefore to identify the advantages and drawbacks of each tool , with respect to the objectives of the project.

From this review, five of the most relevant modelling tools have been selected. They will be analyzed more in detail and tested on the selected contaminated sites as part of the project. Thereafter, a comparison of the results will be performed and will be subject to the next deliverable D.4.1 "*Comparison and validation of risk assessment tools*".

5. References

Arbeitsgemeinschaft der leitenden Medizinalbeamtinnen und Beamten der Länder (AGLMB**).** 1995. Standards zur Expositionsabschätzung, Bericht des Ausschusses für Umwelthygiene (Behörde für Arbeit Gesundheit und Soziales, Hrsg.), Hamburg.

Australian Standard/New Zeland Standard (AS/NZS**).** 2004a. Risk management. AS/NZS 4360:2004, Standards Australia International, Sydney..

Australian Standard/New Zeland Standard (AS/NZS**).** 2004b. Risk management guidelines companion to AS/NZS 4360:2004. HB 436:2004, Standards Australia International, Sydney.

Australian and New Zealand Environment Conservation Council/National Health and Medical Research Council (ANZECC/NHMRC). 1992. Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites.

Béranger, S., Blanchard, F., Archambault, A. and Allier, D. 2006. Utilisation des Outils d'Aide à la Decision dans la Gestion des Mégasites, Rapport brgm RC/RP-55223-FR.

Canadian Council of Ministers of the Environment (CCME**).** 1996. Guidance Manual for developing site specific soil remediation objectives for contaminated sites, Canadian Council of Ministers of the Environment.

Clarinet working group report. 2002. An Analysis of National and EU Research Programmes Related to Sustainable Land and Groundwater Management. Edited by Van Veen, J. H. et. al.; published by Austrian Federal Environment Agency on behalf of Clarinet.

Clement, T.P., Sun, Y., Hooker, B. S. and Petersen, J.N. 1998. Modelling multi-species reactive transport in groundwater aquifers, Groundwater Monitoring & Remediation Journal, 18 (2), 79-92.

Costes, J.M., Texier, J., Zmiron, D. and Lambrozu, J. 1995. A priorization system for former gaswork sites based on the sensitivity of the environment, Contaminated Soil '95 (W.J. van den Brink, R. Bosman and F. Arendt, eds), Kluwer, Dordrecht, 605–607.

CSA. 1997. Risk Management: Guideline for decision-makers (CAN/CSA-Q850-97), Canadian Standards Association.

EC. 1996. Technical Guidance Document in support of Commission Directive 93/67/EEC on risk assessment for new notified substances and Commission Regulation (EC) 1488/94 on risk assessment for existing substances. Parts I, II, III and IV. Document. ISBN 92-827-8011-2. Office for official publications of the European Communities, Luxembourg.

Deere D. and Davidson P. 2005. The Ps and Qs of risk assessment, Water (March 2005).

Dovers, S.R. and Handmer, J.W. 1995. Ignorance, the precautionary principle and sustainability, Ambio 24 (2), 92–97.

Environment Agency. 1997. Taking account of costs and benefits, Bristol.

European Environment Agency (EEA)**.** 1999. Second technical workshop on contaminated sites, working paper workshop proceedings prepared by the European Topic Centre on Soil.

European Environment Agency (EEA)**.** 2007. Progress in management of contaminated sites (CSI 015) – Assessment published Aug 2007, European Environment Agency.

Fairman, R. and Mead, C. 1996. Approaches to Risk Assessment. Unpublished.

Fairman, R, Mead C.D and Williams W.P. 1999. Environmental risk assessment: Approaches, experiences and information, Environmental issue report No 4., EEA (European Environment Agency), EU bookshop ISBN / ISSN: ISBN: 92-9167-080-4.

FAO/WHO. 1997. Risk management and food safety. Report of a Joint FAO/WHO Expert Consultation. Food and Nutrition Paper No. 65.Rome, FAO.

Fetter C. W., 2001. Applied Hydrogeology Fourth Edition. New Jersey, Prentice-Hall, 598 p.

Ferguson, C., Darmendrail, D., Freier, K., Jensen, B.K., Jensen, J., Kasamas, H., Urzelai, A. and Vegter, J. 1998. Risk Assessment for Contaminated Sites in Europe. Volume 1. Scientific Basis, LQM Press, Nottingham.

Hempfling, R., Doetsch, P., Stubenrauch, S., Mahr, A., Bauer, O., Koschmieder, H.J. and Grünhoff, D. 1997. UMS-System zur Altlastenbeurteilung - Instrumente für die pfadübergreifende Abschätzung und Beurteilung von altlastenverdächtigen Flächen, Abschlußbericht F+E-Vorhaben 109 01 215, Umweltbundesamt (UBA), Berlin.

INCORE. 2003. Integrated Concept for Groundwater remediation – INCORE [final report], Stuttgart. 28p.

Landis, Matthews, R. and Matthews, G. 1995. A contrast of human health risk and ecological risk assessment: Risk assessment for an organism versus a complex nonorganismal structure, Human and Ecological Risk Assessment 1 (5), 485-488.

McDonald, H. R. and Harbaugh, A. W. 1984. A modular three-dimensional finite-difference ground-water flow model. U.S. Geological Survey.

Moen, J.E.T., Jansen, M.P.M., Slaper, H. and Lembrechts, J.F.M.N. 1994. Risicovergelijking tussen starling/stoffen, eerste tussenrapport. RIVM no. 610 052 001, Bilthoven.

National Research Council (NRC**).** 1983. Risk assessment in the Federal Government: Managing the Process. National Academy Press, Washington, D.C.

National Research Council. (NRC**).** 1994. Science and Judgement in Risk Assessment. National Academy Press, Washington, D.C.

National Research Council. (NRC**).** 1996. Understanding Risk: Informing Decisions in a Democratic Society. Paul C. Stern and Harvey V. Fineberg, Editors. National Academy Press, Washington, D.C.

O´Brien, M.H. 1994. The scientific imperative to move society beyond 'just not quite fatal', The Environmental Professional, 16, 356–365.

Pollock, D. W. 1989. Documentation of computer programs to compute and display pathlines using results from the U.S. Geological Survey modular three-dimensional finite-difference ground-water model. U.S. Geological Survey Open File Report 89-381.

Royal Society. 1992. Risk analysis, perception and management. The Royal Society, London, ISBN 0-85403-467-6.

Salt, D.E., Blaylock, M., Kumar, P.B.A.N., Dushenkov, V., Ensley, B.D., Chet, I. and Raskin, I. 1995. Phytoremediation: a novel strategy for the removal of toxic metals from the environment using plants, Bio/Technology, 13, 468–478.

Schroeder, P.R. Gibson, A. C. and Smolen, M. D. 1984. The Hydrologic Evaluation of Landfill Performance (HELP) Model, Handbook and Documentation. Environmental Protection Agency, Washington, DC.

Shrader-Frechette, K. 1996. Methodological rules for four classes of scientific uncertainty, Scientific Uncertainty and Environmental Problem Solving (J. Lemmons, ed.). Blackwell Science, Oxford (ISBN 0-86542-476-4).

Siegrist R.L. 1989. International review of appreaches for establishing cleanup goals for hazardous waste contaminated land, Final res. rept. to Norwegian State Poll. Cont. Agency by Inst. for Georesources and Pollution Res., Aas-NLH, Norway, 81 p.

Slob, W. and Pieters, M.N. 1997. A probabilistic approach for deriving acceptable human intake limits and human health risks from toxicological studies: General framework. Report no. 620 110 005. National Institute of Public Health and the Environment (RIVM), The Netherlands.

Smith R., Pollard S.J.T., Weeks J.M. and Nathanail C.P. 2005. Assessing significant harm to terrestrial ecosystems from contaminated land, Soil Use and Management, 21, 527-540.

SPAQuE. 2007. Guide pratique d'utilisation des normes pour le sol et l'eau souterraine- service des expertises de sols- DRAFT document de consultation.

Suter, G.W. II, Vermeire, T., Munns, W.R. Jr. and Sekizawa, J. 2003. Framework for the integration of health and ecological risk assessment, Human and Ecological Risk Assessment 9, 281-302.

Teutsch, G., Ptak, T., Schwarz, R., and Holder, T. 2000. Ein Neues Verfahren zur Quantifizierung der Grundwasserimmission, Teil I: Beschreibung der Grundlagen, Grundwasser, 4(5), 170-175.

UK Department of the Environment, Transport and the Regions (forthcoming) The Contaminated Land Exposure Assessment Model (CLEA): Technical basis and algorithms. CLR report no. 10. DETR, London.

United Nations Environment Programme (UNEP) **and French Agency for the Environment and Energy Management** (ADEME). 2005. Identification and Management of Contaminated Sites, A methodological guide. Paris, Ademe Edition, 117p.

U.S. Environmental Protection Agency (EPA)**.** 1988. Superfund Exposure Assessment Manual. Environmental Protection Agency, Washington, DC.

U.S. Environmental Protection Agency (EPA)**.** 1996. Draft Proposed Guidelines for Ecological Risk Assessment, Risk Assessment Forum, Washington, D.C.

U.S. Environmental Protection Agency (EPA)**.** 1996. Soil Screening Guidance: User's Guide. EPA Document Nb. EPA/540/R-96/018.

U.S. Environmental Protection Agency (EPA)**.** 1997. Policy for use of probabilistic analysis in risk assessment, Guiding Principles for Monte Carlo Analysis in Risk-Assessment.

U.S. Environmental Protection Agency (EPA)**.** 2007. Cleanup Process. U.S. Environmental Protection Agency. http://www.epa.gov/superfund/cleanup/index.htm

Van den Berg, R. 1991/1994. Human exposure to soil contamination: A qualitative and quantitative analysis towards proposals for human toxicological intervention values. Report no. 725 201 011. National Institute of Public Health and the Environment (RIVM), The Netherlands.

Vlek, C.A.J. 1990. Beslissen over risico-acceptatie/Decision-making about risk acceptance, Rapport in Hoofdlijnen/Executive Summary, 52 p, Report no. A90/10H (main report no. A90/10, 236 p, in Dutch), Gezondheidsraad/National Health Council, The Hague.

Weinberg, A.M. 1972. Science and trans-science, Minerva X 2, 202–222.

WELCOME. 2002. Cost-Efficiency Assessment of Megasite Management Options [as part of the European Research Project WELCOME]. ZAG – Annual Report.

Wynne, B. 1972. Uncertainty and environmental learning: reconceiving science and policy in the preventive paradigm, Global Environmental Change 2, 111–127.

Zheng, Chunmiao. 1990. MT3D: A modular three dimensional transport model for simulation of advection, dispersion and chemical reactions of contaminants in groundwater systems. Report to the U.S. Environmental Protection Agency, Ada, Ok, 170 p.

Annexes

Annex 1: Definitions

Definition of some words necessary for the good understanding of the risk assessment concept.

Analysis	The analytical phase of the risk assessment in which the potential for adverse effects are calculated based on the hazard identification, dose-response assessment, and the exposure assessment.
Assessment endpoint	Functions or characteristics of a group or population of people or organisms (such as reproduction, growth, and lack of disease) that can be measured in relation to the intensity or concentration of a stressor.
Conceptual model	A diagram or written description of the predicted key relationships between the stressor(s) and the assessment endpoint(s) for a risk assessment
Ecological Risk Assessment	Ecological risk assessment is the process of estimating the potential impact of a chemical or physical agent on a human population under a specific set of conditions
Ecosystem	An area of nature including living organisms and non-living substances interacting to produce an exchange of material between the living and non-living parts. The term ecosystem implies interdependence between the organisms comprising the system.
Environmental Impact Assessment	An assessment required by the National Environmental Policy Act to evaluate fully potential environmental effects associated with proposed federal actions.
Exposure	Contact with a chemical, physical or biological agent.
Exposure Assessment	The estimation (qualitative or quantitative) of the magnitude, frequency, duration, route and extent of exposure to a chemical substance or contaminant.
Hazard	The capacity to produce a particular type of adverse health or environmental effect, e.g. one hazard associated with benzene

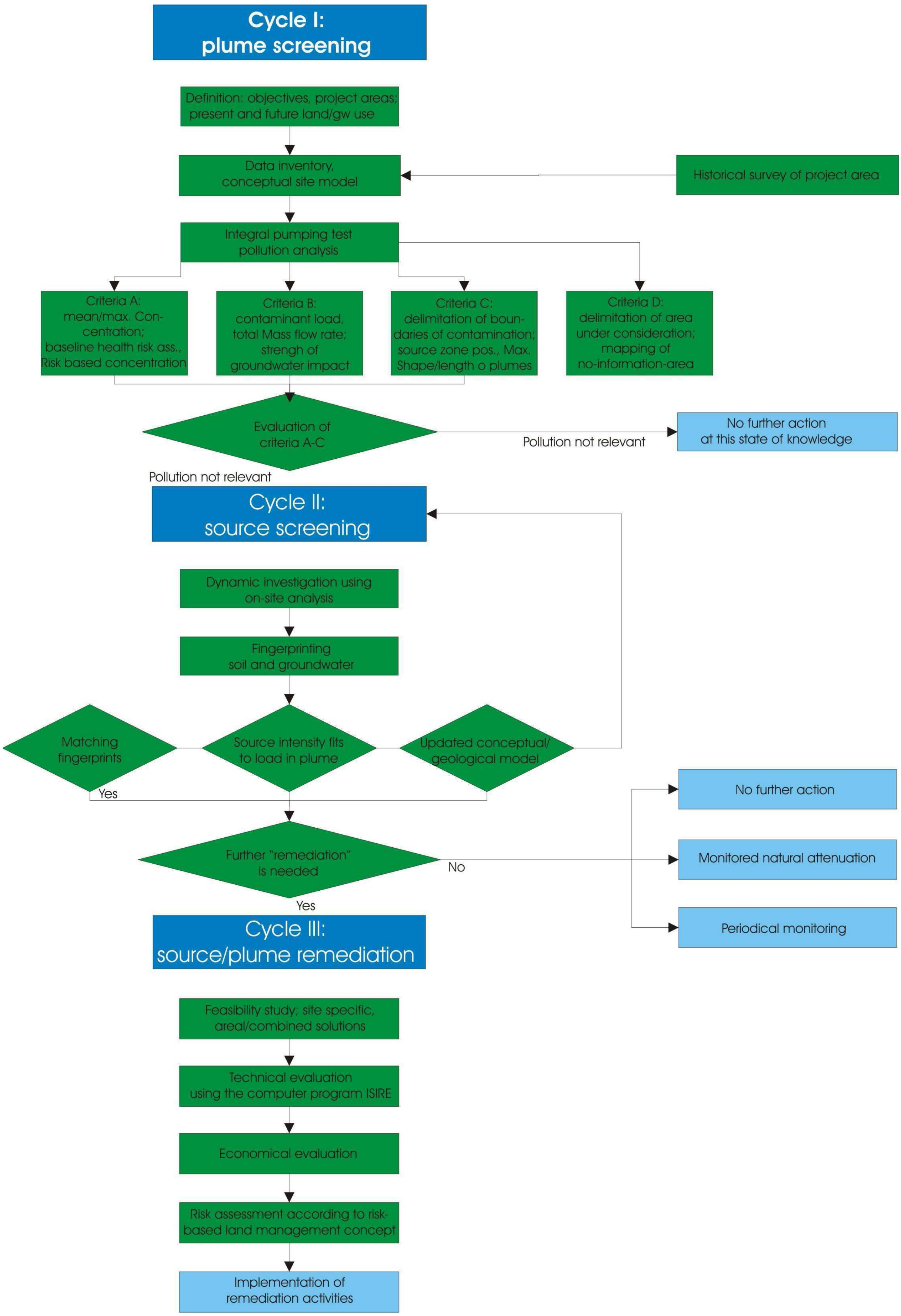
is leukemia.

Health Risk Assessment	Health risk assessment is the process of estimating the potential impact of a chemical or physical agent on a human population under a specific set of conditions.
Integrated Risk Assessment	A process that combines risks from multiple sources, stressors, and routes of exposure for humans, biota and ecological resources in one assessment with a defined point of focus (See also cumulative risk assessment).
Megasite	Is a large area (indicative size: 5 - 500 km2) with multiple contaminant sources related to (former) industrial activities, with a significant impact on the environment, through groundwater, surface water and/or air migration. Due to its complexity related to site conditions, contaminant characteristics, organization, regulatory aspects and/or considerable costs, an integrated risk-based management approach is recommended to manage the risks for the defined receptors
Receptor	An organism, plant, human or physical structure which may be exposed to a chemical or other hazardous agent.
Risk Management	The process of evaluating alternative actions and selecting options in response to risk assessments. The decision making may incorporate scientific, social, economic and political information. The process requires value judgements, e.g. on the tolerability of risk and the reasonableness of costs.
Source	An entity or action that releases to the environment or imposes on the environment chemical, biological, or physical stressor or stressors.
Toxicity	The quality or degree of being poisonous or harmful to plant, animal, human or other life.

Annex 2: International approaches to ecological risk assessment

Country/basis	Limitations, benefits and features	Reference
Australia		
Derivation of ecological risk-based cleanup goals to protect terrestrial receptors.	Background concentrations used as default for cleanup criteria if site specific data is unavailable. Ecological receptors selected to include different trophic levels. Lack of national policy to require criteria to be applied.	Benker *et al.* 2000
Canada		
Recommended Canadian soil quality guidelines; interim environmental quality criteria for contaminated sites; Guidelines for ecological risk assessment; Protocol for the derivation of soil quality criteria.	Includes site specific data and predictive modelling to derive quantitative information on complex ecosystem responses including chronic effects and interactions between chemicals and ecosystem level studies.	Canadian Council of Ministers of the Environment 1998
Denmark		
Use of NOEC, LOEC and EC, extrapolation of laboratory and field data with use of application factors as a safety margin. Aim to protect function and structure of soil.	Soil protection strongly linked to groundwater protection. Funding is remediation driven. Assumes log-normal distribution. Only a fraction of species present in the ecosystem are usually covered by toxicity data. This therefore assumes that protection of those species will be sufficient to protect ecosystem function and structure.	Guideline documents on soil quality criteria. Oliebranchens Miljøpulje (petroleum tax for petroleum contamination remediation). Technology development fund for soil and groundwater innovative remediation techniques.
Germany		
Federal Soil Protection Act 1999 and accompanying Soil Protection Ordinance designed to protect and restore soil functions.	Soil protection has to be considered in relation to the anthropogenic use of the soil. Establishes what constitutes soil contamination. Soil organisms have not yet been considered.	Wilke 2000; CLARINET 2001
Italy		
Maximum admissible concentrations derived. If MAC values are exceeded, then the land is classed as contaminated and clean-up liability is initiated.	Ecological criteria not yet used in the development of MAC values.	Tunesi & D'Amico 2000
The Netherlands		
Soil Protection Act 1994, as amended.	The Soil Protection Act aims to prevent, restrict or remedy changes of soil properties, which entail a reduction of or a threat to the functional properties the soil has for man, flora and fauna.	Breure & Peijnenburg 2003 Crommentuijn *et al.* 1997
Suitable for use approach, HC_{50} applied to land use types. Maximum permissible soil concentrations defined. A log distribution of NOEC data provides species sensitivity distributions (SSD). The serious risk concentration is derived by the 50[th] percentile of the SSD.	Assumes it is acceptable for 50% of the organisms involved to be exposed to contamination levels higher than their NOEC. Toxicity of pollutants for land use specific ecological parameters are mostly unavailable and are highly arbitrary.	Crommentuijn *et al.* 2000 Faber 1998
Circular on target values and intervention values for soil remediation 2000.	Remediation is geared to the desired end use. Intervention values, indicative levels for serious contamination and target values equally apply to aquatic sediment.	Netherlands Ministry of Housing Spatial Planning and the Environment 1994
In March 2004, the Dutch Government announced proposals to amend the Soil Protection Act as a result of a change in policy. If adopted, the change would result in soil remediation being carried out by combined public and private investment (present system uses public finance) to reduce the timescales involved to around one generation.		Netherlands Ministry of Housing Spatial Planning and the Environment 2000 van Wensem *et al.* 2000
Sweden		
Contaminated land assessment is related to hazard and levels of pollutants, taking into account their migration potential, site sensitivity and protective value. General framework and guideline values which do not pose unacceptable risks to the environment, to indicate the degree of contamination on a site, to develop clean-up goals and to evaluate clean-up results.	Policy driven by increasing acidification in SW Sweden and nutrient deficiency in forests.	Swedish Environment Code 1998
Switzerland		
Swiss Ordinance Relating to Pollutants in Soil (1986) and the Ordinance Relating to Impacts on the Soil (1998).	Adopts intervention values for guide, trigger and clean-up. Evidence of widespread contamination; precautionary guide values for inorganic soil contaminants (Appendix 1 of the Ordinance relating to Contaminants in Soil of 1st July 1998) have been exceeded in 42% of the National Soil Monitoring Network's study sites, primarily in topsoil. Main contaminants are Pb, Cu, Cd.	Swiss Agency for the Environment, Forests and Landscape 2000.
UK		
Tiered approach for assessing soil contaminants only on the basis of the legal definition of harm as contained in Part IIA. Uses a weight-of-evidence approach. Soil screening values used for effects assessment.	Consultation framework. Existing soil screening values are limited though they are being developed.	Environment Agency 2003
USA		
Tiered approach to ecological risks associated with contaminated soil. Developing a programme to develop ecological (risk) soil screening levels as toxic reference values (Oak Ridge Toxicological Benchmarks).	Standardisation is minimised. Based mainly on characteristics and need of decision makers. Comparable to human health risk-based screening concentration (RBC) values.	United States Environmental Protection Agency 1998 Sample & Suter 1994 Sample *et al.* 1996 Sample *et al.* 1997 Sample *et al.* 1998a Sample *et al.* 1998b Sample *et al.* 1998c

Annex 3: INCORE flow chart (adapted from INCORE, 2003)



Annex 4: Tools developed in the scope of The WELCOME project (adapted from Béranger and al., 2006)

Step of the IMS	WELCOME tools	Purpose
Starting IMS		
Problem definition		
Organizing stakeholders		
Boundary conditions		
Inventory of information		
Building a conceptual model		
Decision on IMS	ROCO	Costs estimation
Risk assessment		
Megasite characterization	PRICON	Defining priority contaminants
	DEMONA	Natural attenuation
	SEDINA	Natural attenuation in the sediments
	DSM-NA	Natural attenuation at the interface between groundwater and surface water
Clustering		
Modelling	CARO	Cost analysis of remediation options
	BAM	Natural attenuation of sediments and soils
Determining risks	RAS	Risk assessment
Finalize clustering		
Risk management scenarios		
Basic scenarios	PRESTO	Preselection of treatment options
	HEMENA	Heavy Metal Enhanced Natural Attenuation
Potential and prefered scenario	CARO	Cost analysis of remediation options
Final scenario		
Implementation		
Management plan		
Monitoring program		
Review process		

Annex 5: Fact sheets on the decision support and modelling tools

ACRONYM	**ABC-TOOL**
Complete title	Assessment of Benefits and Costs of remedial actions
Author(s)	Netherlands Organisation for Applied Scientific Research-TNO
Website/References	http://www.euwelcome.nl/kims/tools/index.php?index=110

Description/Functionalities

ABC-TOOL is a decisional and economical tool allowing identifying and examining the feasibility of different remediation techniques. It consists of three modules:

(1) Assessment: determination of the feasibility of remediation techniques for a specific site;

(2) Benefits: determination of environmental load and merit of techniques;

(3) Costs: evaluation of costs per technique and per country.

Comments

ABC-TOOL is used according to some conditions:

Type of contaminants	Media
Hydrocarbons Chlorinated solvents Metals	Heterogeneous sand/clay/loam/peat Homogeneous sand Homogeneous clay

It considers the groundwater flow velocity as a main criterion for the choice of the remediation technique.

ACRONYM	**ARAMS**
Complete title	Adaptive Risk Assessment Modeling System
Author(s)	U.S. Army Engineer Research and Development Center (ERDC) and U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM)
Website/References	http://el.erdc.usace.army.mil/arams/

Description/Functionalities

ARAMS is an analysis software with wide database and modeling tools used to describe the pollutant source and to integrate media fate and transport, exposure pathways, intake and uptake, and effects/impacts of contaminants into a conceptual site model (CSM) framework. It includes:

- Analytical modeling;
- Uncertainty analysis;
- Statistical analysis;
- Conceptual site model;
- Human health risk assessment;
- Ecological risk assessment.

Comments

ARAMS is used according to some conditions:

Type of contaminants	Media
Chlorinated solvents Metals Semi-volatile organic compounds Pesticides/PCBs Hydrocarbons Radionuclides	Soil sediment Air Surface water Groundwater

The chemical reactivity of pollutants is not considered in the software. The GIS tool is still not fully working.

ACRONYM **CAMEO**

Complete title Computer-Aided Management Of Emergency Operations

Author(s) U.S. Environmental Protection Agency Office of Emergency Management (OEM) and the National Oceanic and Atmospheric Administration Office of Response and Restoration (NOAA)

Website/References http://www.epa.gov/emergencies/content/cameo/index.htm

Description/Functionalities

CAMEO is a decision support tool used to plan for and respond to chemical emergencies. It includes:

- Analytical modeling;
- Database;
- Chemical reactivity analysis;
- Emergency response tool;
- Regulatory reporting.

Comments

CAMEO is used according to some conditions:

Type of contaminants	Media
Chlorinated solvents Metals Semi-volatile organic compounds Hydrocarbons Radionuclides	Soil sediment Soil gas Air Surface water Groundwater

The study on the fate and transport of contaminant, the exposure pathways and impacts on the ecosystems are not included in this tool.

ACRONYM	**CHEMFLO 2000**
Complete title	Chemflo 2000
Author(s)	D.L. Nofziger and Jinquan Wu
Website/References	http://soilphysics.okstate.edu/software/chemflo/

Description/Functionalities

Chemflo 2000 was developed to simulate water movement and fate and transport of contaminants in unsaturated media. It includes:

- Numerical modeling;
- Sensitivity analysis.

Comments

CHEMFLO 2000 is used according to some conditions:

Type of contaminants	Media
All	Soil Groundwater

The models used by CHEMFLO 2000 assume a strictly one-dimensional flow and transport in the soil and constant soil hydraulic properties.

ACRONYM	**DESYRE**
Complete title	DEcision Support sYstem for REhabilitation of contaminated sites
Author(s)	Venice Research Consortium in collaboration with the University of Venice, Ca' Foscari (Dep. of Environmental Sciences and Mathematics), Thetis Spa and CNR-ISE.
Website/References	http://venus.unive.it/eraunit/research_group_projects.htm#desyre

Description/Functionalities

DESYRE is a very sophisticated tool integrating environmental and technological databases, risk assessment models, and multi-criteria procedures. It includes:

- Analytical modeling;
- Geographic information system (GIS);
- Human health risk assessment;
- Remediation tool.

DESYRE is composed of five modules: (1) characterisation – collect of information about the contaminated site, (2) risk – development of models for the analysis of fate, transport and exposure, (3) socio-economical – evaluation of constraints and benefits, (4) technological analysis – evaluation of the feasibility, advantages, limits and costs of remediation techniques, and (5) decision.

Comments

DESYRE is used according to some conditions:

Type of contaminants	Media
All	All

DESYRE allows performing pre and post remediation spatial risk assessment for human health. The ecological risk assessment is currently in process.

ACRONYM	**FIELDS Tools for ArcGIS©**
Complete title	FIELDS Tools for ArcGIS©
Author(s)	EPA Region 5 FIELDS Team
Website/References	http://epa.instepsoftware.com/fields/

Description/Functionalities

FIELDS Tools for ArcGIS is a tool for data analysis and interpretation for environmental decision-making. It allows evaluating the extent of contamination and "hot spot" sizes, estimating risks for human health and environment, prioritizing site goals and weighing potential actions. It includes:

- Analytical modeling;
- Database (includes a query tool);
- Sample design;
- Geospatial modeling and analysis;
- Ecological risk assessment;
- Human health risk assessment;
- Cost/benefits analysis;
- Remedial tools.

Comments

FIELDS is used according to some conditions:

Type of contaminants	Media
Chlorinated solvents Metals Semi-volatile organic compounds Pesticides/PCBs Hydrocarbons Radionuclides	Soil sediment Soil gas Surface water Groundwater

FIELDS tends to provide the required information for Tier 2 (complex models for fate and transport of contaminants).

ACRONYM	**GEOSEM**
Complete title	GEOSpatial Exposure Model
Author(s)	SRC (Syracuse Research Corporation)
Website/References	http://esc.syrres.com/geosem/default.htm

Description/Functionalities

GEOSEM is a program for incorporating spatial statistics in human health and ecological exposure assessment. It includes:

- Analytical modeling;
- Geographic information system (GIS);
- Visualization;
- Uncertainty analysis;
- Statistical analysis;
- Geospatial interpolation.

Comments

GEOSEM is used according to some conditions:

Type of contaminants	Media
Chlorinated solvents Metals Semi-volatile organic compounds Pesticides/PCBs Hydrocarbons Radionuclides	Soil sediment Soil gas Surface water Groundwater

ACRONYM	**GroundwaterFX**
Complete title	GroundwaterFX
Author(s)	DecisionFX
Website/References	http://www.decisionfx.com/GWFX.html

Description/Functionalities

Groundwater*FX* is a decision support tool that provides information regarding the necessary number and location of monitor wells to delineate the nature and extent of a contaminant plume. It also provides visual feedback on the nature and extent of the contamination. Groundwater FX :

- Utilizes flow and transport models in a probabilistic framework to account for uncertainty in contaminant movement ;
- Decision support tool to optimize the number and placement of monitor wells to delineate the nature and extent of a contaminant plume ;
- Utilizes optimization theory to minimize the number and cost of monitor wells and boreholes for sampling locations ;
- Simplifies the analysis of natural attenuation potential.

Comments

GroundwaterFX is used according to some conditions:

Type of contaminants	Media
Not mentioned	Groundwater

ACRONYM	**Groundwater Sensitivity Toolkit**
Complete title	Groundwater Sensitivity Toolkit
Author(s)	GSI Environmental Inc.
Website/References	http://www.gsi-net.com/Software/GroundwaterSensitivity.asp

Description/Functionalities

Groundwater Sensitivity Toolkit was developed to evaluate the sensitivity of groundwater resource to a potential release of contaminants at a particular site. It includes a site screening tool.

Comments

Groundwater Sensitivity Toolkit is used according to some conditions:

Type of contaminants	Media
Chlorinated solvents Metals Hydrocarbons	Groundwater

ACRONYM	**HSSM**
Complete title	Hydrocarbon Spill Screening Model
Author(s)	Robert S. Kerr Environmental Research Laboratory Office of Research and Development U.S. Environmental Protection Agency
Website/References	http://www.epa.gov/ada/csmos/models/hssmwin.html

Description/Functionalities

HSSM has as objectives to simulate releases of light non aqueous phase liquids (LNAPLs) to the subsurface environment and to estimate the impacts of pollutants on the aquifers. It includes:

- Analytical modeling;
- Visualization;
- Screening tool.

Comments

HSSM is used according to some conditions:

Type of contaminants	Media
Chlorinated solvents Hydrocarbons	Soil sediment Groundwater

HSSM may be used to give a rough estimation of pollutants concentrations in groundwater.

The discretization of flow domain and the techniques of iterative solution are not integrated in the software.

ACRONYM	**MASSFLUX TOOLKIT**
Complete title	Mass Flux Toolkit
Author(s)	GSI Environmental Inc.
Website/References	http://www.gsi-net.com/Software/massfluxtoolkit.asp

Description/Functionalities

Mass Flux Toolkit is a tool focused on different mass flux approaches. It allows calculating mass flux from transect data and applying mass flux values to manage groundwater plumes for various pollutants. It includes:

- Analytical modeling;
- Module for the calculation of the total mass flux across one or more transects of a plume;
- Uncertainty analysis on the calculation of mass flux;
- Module for critical dilution calculations for plumes.

Comments

Mass Flux Toolkit is used according to some conditions:

Type of contaminants	Media
Chlorinated solvents Metals Semi-volatile organic compounds Pesticides/PCBs Hydrocarbons Radionuclides	Groundwater

It provides information about effects of remediation/impacts of natural attenuation processes.

ACRONYM	**NAS**
Complete title	Natural Attenuation Software
Author(s)	Southern Division, Naval Facilities Engineering Command (NAVFAC) and Naval Facilities Engineering Service Center (NFESC)
Website/References	http://www.nas.cee.vt.edu/index.php

Description/Functionalities

NAS is a graphical user interface in order to estimate the time required to achieve site-specific goals at contaminated sites. It includes:

- Analytical modeling;
- Numerical modeling;
- Visualization;
- Remedial process selection.

Comments

NAS is used according to some conditions:

Type of contaminants	**Media**
Chlorinated solvents Metals Semi-volatile organic compounds Hydrocarbons Radionuclides	Groundwater

NAS is designed for an application in groundwater with a relatively homogeneous and saturated porous media, and assumes that groundwater flow is uniform and uni-directional.

ACRONYM	**ONSITE**
Complete title	On Site
Author(s)	National Exposure Research Laboratory Office of Research and Development U.S. Environmental Protection Agency
Website/References	http://www.epa.gov/athens/onsite

Description/Functionalities

On Site was developed to evaluate transport of contaminants in the subsurface. It includes:

- Analytical modeling;
- Sensitivity analysis.

Comments

On Site is used according to some conditions:

Type of contaminants	Media
Chlorinated solvents Metals Semi-volatile organic compounds Pesticides/PCBs Hydrocarbons Radionuclides	Soil sediment Air Surface water Groundwater

On Site includes contaminant fate and transport in one dimension.

ACRONYM **PRO UCL**

Complete title Upper Confidence Limit

Author(s) EPA Technical Support Center (TSC)

Website/References http://www.epa.gov/esd/tsc/software.htm

Description/Functionalities

PRO UCL is software to support risk assessment and cleanup decisions at contaminated sites. It estimates the 95 percent upper confidence limit (UCL) of an unknown population mean of environmental data sets. It includes a statistical analysis.

- Estimate the exposure point concentration (EPC) term,
- Determine the attainment of cleanup standards,
- Estimate background level mean contaminant concentrations, or
- Compare the soil concentrations with site specific soil screening levels.

Comments

PRO UCL is used according to some conditions:

Type of contaminants	Media
Chlorinated solvents Metals Semi-volatile organic compounds Pesticides/PCBs Hydrocarbons Radionuclides	Soil sediment Air Surface water Groundwater

PRO UCL is often used to estimate the exposure point concentration, to support risk assessment applications, to determine the attainment of cleanup standards, to estimate the background level mean contaminant concentrations and to compare the soil mean concentrations with site-specific soil screening levels.

ACRONYM	**RAT**
Complete title	Rapid Assessment Tool
Author(s)	EPA Region 5 FIELDS Team
Website/References	http://epa.instepsoftware.com/rat/

Description/Functionalities

RAT is a Microsoft Windows based software package facilitating field data collection in real-time. It includes:

- Visualization;
- Data acquisition;
- Data management.

Comments

RAT is used according to some conditions:

Type of contaminants	Media
Chlorinated solvents Metals Semi-volatile organic compounds Hydrocarbons Radionuclides	Soil sediment Air

ACRONYM	**RBCA TOOLKIT**
Complete title	Risk Based Corrective Action
Author(s)	RBCA Framework (American Society for Testing and Materials) and RBCA Tool Kit (Groundwater Services Inc., USA)
Website/References	http://www.groundwatersoftware.com/rbca_tool_kit.htm

Description/Functionalities

The RBCA Toolkit is a management approach used to assess actual/possible human and environmental risks caused by exposure to chemical releases. It also helps to determine appropriate remedial actions in response to such releases. It includes:

- Analytical modeling;
- Deterministic modeling;
- Natural attenuation modeling;
- Reactional analysis of contaminants;
- Transient modeling options;
- Possibility to insert dilution/delay factor to concentrations values.

Comments

RBCA Toolkit is used according to some conditions:

Type of contaminants	Media
Chlorinated solvents Metals Semi-volatile organic compounds Hydrocarbons Radionuclides	All

The uncertainty analysis is not incorporated in RBCA Toolkit. Moreover, it is not able to simulate contaminant concentrations down-gradient of a discharge point for surface water.

ACRONYM	**RESRAD**
Complete title	RESidual RADioactivity
Author(s)	Environmental Assessment Division Argonne National Laboratory United States Department of Energy
Website/References	http://web.ead.anl.gov/resrad/home2/

Description/Functionalities

RESRAD is a code developed to assess risks posed by radioactively contaminated sites on human and environment. It includes:

- Analytical modeling;
- Human health risk assessment;
- Ecological risk assessment;
- Uncertainty analysis;
- Sensitivity analysis;
- Cost/benefits analysis.

Comments

RESRAD is used according to some conditions:

Type of contaminants	Media
Radionuclides	Soil sediment Air Surface water Groundwater

RESRAD assists in developing cleanup criteria.

ACRONYM	**RISC WorkBench**
Complete title	Risc WorkBench
Author(s)	Scientific Software Group
Website/References	http://www.scientificsoftwaregroup.com/pages

Description/Functionalities

RISC WorkBench is software package used to perform fate and transport modeling and human health/ecological risk assessments for contaminated sites. It is based on the standard procedures outlined in the U.S EPA's Risk Assessment Guidance for Superfund (U.S EPA, 1989) in order to calculate exposure assessment, toxicity assessment and risk assessment. It includes:

- Analytical modeling;
- Human health risk assessment;
- Ecological risk assessment;
- Deterministic modeling;
- Stochastic modeling.

Comments

RISC WorkBench is used according to some conditions:

Type of contaminants	Media
Chlorinated solvents Metals Semi-volatile organic compounds Pesticides/PCBs Hydrocarbons Radionuclides	Soil sediment Surface water Groundwater

The ecological risk assessment is principally focused on the water quality.

ACRONYM	**SADA**
Complete title	Spatial Analysis and Decision Assistance
Author(s)	The United States Environmental Protection Agency (Region 5 FIELDS Group) and The United States Nuclear Regulatory Commission (NRC)
Website/References	http://www.tiem.utk.edu/~sada/index.shtml

Description/Functionalities

SADA is a complete tool performing environmental assessments in support of decision-making. It includes:

- Numerical modeling;
- Geographic information system (GIS);
- Data exploration and visualization;
- Uncertainty analysis;
- Statistical analysis;
- Human health risk assessment;
- Ecological risk assessment;
- Sample plan design;
- Cost/benefit analysis;
- Geospatial interpolation.

Comments

SADA is used according to some conditions:

Type of contaminants	**Media**
Chlorinated solvents Metals Semi-volatile organic compounds Pesticides/PCBs Hydrocarbons Radionuclides	Soil sediment Soil gas Surface water Groundwater

ACRONYM	**SCRIBE**
Complete title	SCRIBE
Author(s)	U.S. Environmental Protection Agency Environmental Response Team (ERT)
Website/References	http://www.ertsupport.org/scribe_home.htm

Description/Functionalities

Scribe is a software tool developed to assist in the process of managing environmental data (Tier 1). It includes:

- Data acquisition;
- Monitoring field data;
- Form/Label generation;
- Database.

Comments

SCRIBE is used according to some conditions:

Type of contaminants	Media
Chlorinated solvents Metals Semi-volatile organic compounds Pesticides/PCBs Hydrocarbons Radionuclides	Soil sediment Air Surface water Groundwater

ACRONYM	**SERDP**
Complete title	Source Depletion Decision Support System
Author(s)	GSI Environmental Inc.
Website/References	http://www.gsi-net.com/Software/serdp_dss.asp

Description/Functionalities

SERDP is a program used to help the decision-making process for remediation of dense non aqueous phase liquid (DNAPLs) source zones. It includes:

- Visualization;
- Data filtering;
- Review research.

Comments

SERDP is used according to some conditions:

Type of contaminants	Media
DNAPL	Groundwater

ACRONYM **SMARTe**

Complete title Sustainable Management Approaches and Revitalization Tools - electronic

Author(s) U.S. Environmental Protection Agency Office of Research and Development and Office of Brownfields Cleanup and Redevelopment

Website/References http://www.smarte.org/smarte/home/index.xml

Description/Functionalities

SMARTe is decision support system used to develop and to evaluate future re-use scenarios for potentially contaminated lands (Tier 3). SMARTe integrates analysis tools concerning all aspects of the revitalization process including:

- Planning;
- Environmental aspect;
- Economic aspect;
- Social aspect.

Comments

SMARTE is still under developed about land-use options analysis, economic analysis calculators, environmental management tools, etc.

ACRONYM	**SOURCE DK**
Complete title	Source DK
Author(s)	GSI Environmental Inc.
Website/References	http://www.gsi-net.com/Software/SourceDK.asp

Description/Functionalities

SourceDK is used to develop a screening-level model in order to estimate groundwater remediation timeframes and to associate uncertainties at sites where groundwater is contaminated by a source in the unsaturated zone. It includes:

- Analytical modeling;
- Uncertainty analysis;
- Chemical reactivity analysis (only biodegradation);
- Remedial process selection.

Comments

Source DK is used according to some conditions:

Type of contaminants	Media
Chlorinated solvents Semi-volatile organic compounds Pesticides/PCBs Hydrocarbons	Groundwater

Source DK is not designed to simulate the effects of chemical diffusion.

It also assumes that all the biodegradation occurs in the dissolved phase and acts only on dissolved constituents.

Source DK is primarily geared for natural attenuation processes.

ACRONYM **VSP**

Complete title Visual Sample Plan

Author(s) Pacific Northwest National Laboratory

Website/References http://dqo.pnl.gov/vsp/

Description/Functionalities

VSP provides statistical solutions to sampling design problems. It helps the user to select the correct number and location of samples to achieve a certain confidence level in the decision-making. It includes:

- Visualization;
- Initial sampling;
- Secondary sampling;
- Statistical analysis;
- Cost/benefit analysis.

Comments

VSP is used according to some conditions:

Type of contaminants	Media
Chlorinated solvents Metals Semi-volatile organic compounds Pesticides/PCBs Hydrocarbons Radionuclides	Groundwater