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Theme D:

RISK BASED LAND MANAGEMENT (SOIL & GROUNDWATER)

D.1 Lecture Session:

Introduction to RBLM:
Environmental Issues

RISK-BASED LAND MANAGEMENT
Towards sustainable management of contaminated land in Europe

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INTRODUCTION

Twenty or so years ago land contamination was usually perceived in terms of relatively rare incidents, with poorly known but possibly catastrophic consequences for human health and the environment. Several incidents attracted major media attention, e.g. Love Canal, New York State; Times Beach, Missouri; Lekkerkerk, the Netherlands. As a result politicians responded by seeking maximum risk control: pollution should be removed or contained completely.

Today land contamination is no longer perceived in terms of a few severe incidents, but rather as a widespread structural problem of varying intensity and significance. It is now widely recognised that drastic risk control, for example cleaning up all sites to background concentrations or to levels suitable for the most sensitive land use, is neither technically nor economically feasible. To give an example, in 1981 about 350 sites in the Netherlands were thought to be contaminated and possibly in need of remedial action. By 1995 the number had grown to 300,000 sites with an estimated cleanup cost of 13 billion EURO. Similar circumstances exist in most other industrialised countries. Consequently, although the need for policies to protect soil and groundwater is recognised, strategies for managing "historical" contaminated land – legacies from past industrial activities – have moved towards sustainable solutions based on *fitness for use* (Ferguson, 1999)

POLICY APPROACHES

Policies traditionally often view contaminated land problems from two main perspectives. The first is the perspective of protection - relating to the impact of contamination on human health and environmental quality. The other is the spatial planning perspective - managing the impact of contaminated land on the way land is used, for example regenerating industrial areas, or increasing agriculture use, or for creating a nature area.

These different perspectives influence the different legal regimes used in different countries: some countries use environmental legislation as the primary means of preventing impacts from land contamination on land use and the environment, others use spatial planning legislation.

The major trend in policy development is to address these two aspects simultaneously *(figure 1).* This is increasingly evident in the development of a more holistic approach to management of urban development. This in turn increasingly links to economic issues, such as changes to land values and use of the market to drive environmental improvements.

Underlying all this is the wider perspective of sustainable development[1], in particular the need to consider the timing of any intervention and the future consequences of any particular solution in relation to environmental, economic, social and cultural dimensions.

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[1] Sustainable development has been defined as: "…. *Development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (Brundtland 1987).

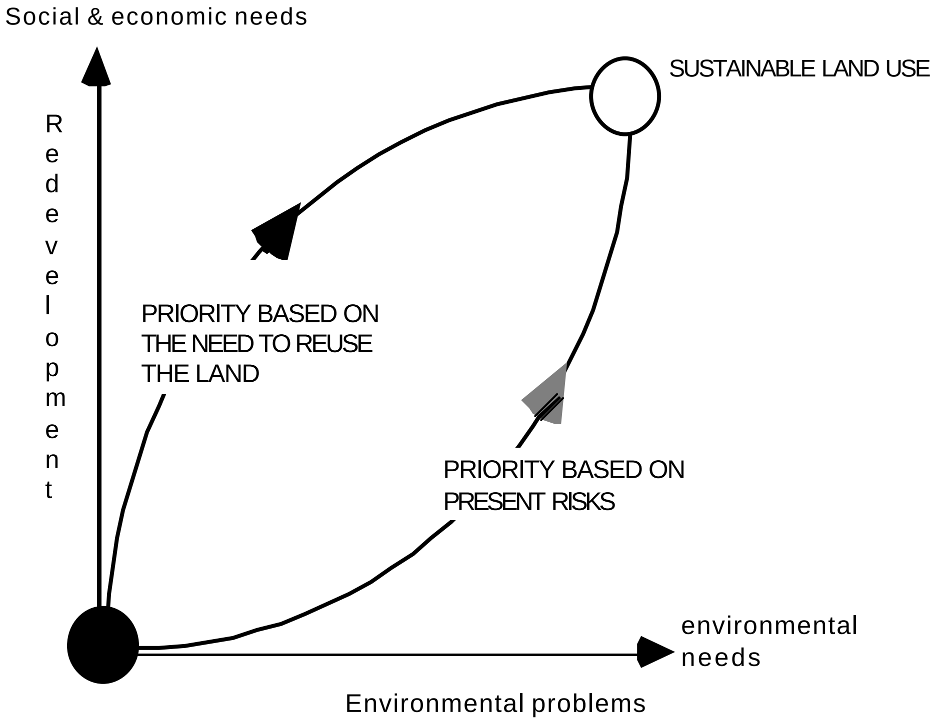

Figure 1: Trend in policy development in European countries: Different drivers for solving contaminated land problems ultimately aim at restoring the capacity to reuse the land. Defining contaminated land problems as a general burden for society instead of a sectoral environmental or spatial planning problem will assist in finding sustainable solutions

THE NEED FOR NEW SOLUTIONS

The focus on developing integrated and sustainable approaches has resulted in a shift in attention from the assessment of problems to the formulation of solutions that will meet both the present and future needs of society.

The need to focus on solutions applies just as much to contaminated land. However, this is taking place against a backdrop of limited information about the full extent and significance of contaminated land, of changing attitudes and systems, and of concerns that decisions taken now should fit within a vision of a sustainable future. Current approaches focus on better-informed and sustainable solutions, which will manage the contamination effectively and restore the social, environmental and economic value of the land.

THE CONCEPT OF RISK BASED LAND MANAGEMENT

CLARINET considers that an intellectual framework for management of contaminated land would assist in structuring this decision-making process to achieve sustainable solutions. The concept of Risk Based Land Management (RBLM) aims to fulfil this role. It focuses on legacy contamination and allows for regional and site-specific solutions in policy and other decision-making across Europe.

Risk Based Land Management is primarily a framework for the integration of two key decisions for remediation of contaminated land:

- **The time frame**: this requires an assessment of risks and priorities, but also the consideration of the longer term effects of particular choices
- **The choice of solution**: this requires an assessment of overall benefits, costs and environmental side effects, value and circumstances of the land, community views and other issues.

These two decisions have to take place at both an individual site level and at a strategic level, especially as the impact of contaminated land on the environment can have not only a large scale regional dimension but also potentially wide ranging long term impacts. The decision making process needs to consider three main components which form the core of the RBLM concept:

- **fitness for use**
- **protection of the environment, and**
- **long-term care**.

The first two describe the goals in relation to a safe use of the land, including prevention of harm and resource protection. The third allows for a more rigorous assessment of the way to achieve these goals in a sustainable way. The three components need to be in balance with each other to achieve an appropriate solution *(see figure 2).*

Figure 2: The architecture of RBLM

THE AIM OF RBLM

The aim of the RBLM concept is to achieve the integration of approaches originating from different perspectives (for example spatial planning, environmental protection and engineering), based on the identification of common goals:

- Comparable levels of protection of health and the environment, taking into account local characteristics;
- Optimised use and development of technical and administrative solutions; and
- Sustainability - evaluating and optimising environmental, economic and social factors

The concept applies at different scales – site, regional, national – and covers the whole cycle of risk assessment and risk management of contaminated land. It is driven by current and emerging scientific knowledge. It links to wider themes, in particular to soil protection, spatial planning, and water catchment management.

The concept also applies at a strategic level. However, it has practical application at a site specific level: the operational details of treatment, monitoring, aftercare and other risk management techniques (containment techniques for instance) can be assessed using the RBLM concept on a site-specific basis.

THE COMPONENTS OF RBLM

Fitness for use

This depends on reducing risks to human health and the environment as necessary to ensure the safe use or reuse of the land. It focuses on quality requirements of the land for uses and functions, and takes into account the timeframe of the particular use of the land – for example the assessment considers how long a receptor might be exposed to contamination.

Risks related to the use of the land should be “acceptable” for the people concerned. This acceptance might be obtained if the quality of the land meets certain minimum quality requirements. In some cases, obtaining acceptance might require additional quality requirements to create confidence and security. It is essential in determining the “total quality requirements" to know all the aspects of the site use. This will ensure that the requirements are appropriate. It is also necessary to consider the future activities and controls on the site to ensure that long term risks are also managed, and that the land will continue to be "fit for use" in the future.

Making certain choices about the management of the land can not only achieve the necessary quality requirements in relation to immediate fitness for use but also improve the quality of the land over time. For example, introducing additional gradual treatment would open up opportunities for land use changes, more biodiversity and less long-term care.

Protection of the environment

Protection of the environment is related to the wider effects, in contrast to those only related to the use of the site[4]. It has two objectives:

- To prevent or reduce negative impact on the natural surroundings, including ecosystem health and biodiversity;
- To conserve and, if possible, enhance the quality and quantity of resources (for example land, soil, water, or cultural heritage)

Accepted principles like the precautionary principle[5] and the preventive principle[6] apply to both these objectives.

Preventing or controlling the dispersion of contamination from a site to the surroundings may often achieve both objectives. For example, preventing further spreading of pollution by surface water and groundwater can be a component of overall risk reduction for contaminated land. Being able to achieve both objectives depends on the uses, functions and characteristics of both the land and the surrounding environment.

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[4] In the UK the term **suitable for use** combines the two concepts of fitness for use and protection of the environment (DETR Circular 2/2000; DoE news release 654/1994)

[5] **Precautionary principle:** Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation

[6] **Preventive principle** The state of the environment should not get worse as a result of pollution that can be avoided. Further pollution of already polluted areas should be avoided. The principle also implies that accumulation of persistent substances in the environment should be stopped

The requirement to achieve both fitness for use and protection of the environment means that solutions have to be chosen carefully. A solution that meets only the fitness for use requirements is probably not the best solution if it creates potential problems in surrounding areas. A solution that manages the dispersion risk may be different from the solution that manages risks to achieve "fitness for use".

Solutions may in turn lead to the exploitation of other resources, such as energy reserves, or land capacity for disposal. Other environmental and spatial planning policies will aim to protect these resources and a balanced decision - or new solutions - will be needed where there is conflict between the objectives of risk reduction and conservation of resources.

The decision to conserve land or soil as a resource may lead to policies favouring redevelopment of brownfields – land previously used, for example by industry, which may be affected by contamination - over greenfields. This in turn may lead to increased pressure to develop new solutions to deal with the risks to health and the environment. It also shows the need for strategies to prevent sites from becoming brownfields.

Long-term care

If a solution leaves contamination in the soil, there is a need for long-term care. Monitoring and control may be necessary to ensure that the solution remains appropriate, that it continues to work and that any restrictions on future choices regarding the land use are enforced.

Solutions that are based on the current use only, or rely on specific restrictions on land use need additional documentary records. Taking into account the social and economic burden of long-term care and the risk of failure is essential in identifying sustainable solutions.

HOW RBLM CAN WORK IN PRACTICE

The way in which the balance between the three components of RBLM is achieved will be different for different treatment approaches. Over the past fifteen years, developments in contaminated land policies and the emergence of a wide range of treatment approaches have broadened the repertoire of potential solutions for contaminated land problems. There can be other options rather than only ‘dig and dump’ or containment.

However, it is clear that there is no universally practical solution. Each solution has its advantages and disadvantages, which depend on a wide range of factors and requirements, such as:

- nature of the contamination
- physical characteristics of the land
- use of the land, either current or planned
- the environmental setting, in particular ecosystems and buildings
- the hydrogeological characteristics and impact on water resources,
- nature of impact on community
- local and regional practicalities

These factors and requirements vary from one situation to another, and as a result the practical availability and appropriateness of solutions needs to be determined on a site-specific basis. The overall balance of disadvantages and benefits can then be determined for those options which are technically possible. RBLM provides a framework for determining this balance in practice.

The choice of any specific practical option, either at a strategic policy level or for a particular site, needs to take into account the extent to which the land meets any fitness for use criteria, achieves adequate protection of the environment or needs longer term care. This assessment is complex, and has already generated a demand for decision support tools, which may vary from straightforward information about the broad advantages and disadvantages of various options to formalised weighting systems.

On the basis of the underlying three components of risk based land management: fitness for use, protection of the environment and long term care, the risk based land manager has to address the following issues in order to ensure a sustainable solution:

- Risk reduction
- Land use related requirements
- Using natural capacities in the soil and water environment
- Costs
- Involving stakeholders
- Managing uncertainties
- Other management constraints and influences

These issues are discussed in more detail in the CLARINET report “Sustainable Management of Contaminated Land”, which is available for download on the CLARINET website *http://www.clarinet.at*.

RBLM WITH REGARD TO SOIL & WATER PROTECTION

The 6th environment action programme[8] states that a thematic strategy for soil protection is needed, in view of the complex nature of the pressures weighing on soils. It is also stressed that a soil policy must be based on a sound basis of data and assessment. Further development of the EU thematic strategy for soil is centred on the draft Soil Protection Communication[9] published by the commission (DG Environment).

CLARINET considers that the RBLM concept should influence the further development of a wider soil protection policy framework. RBLM focuses on site-specific management choices. These must consider adverse effects of contamination on land uses and functions, impacts on surrounding land and water and long-term management considerations. Within the RBLM concept, solutions for contaminated land are flexible and not based on fixed national or supranational numerical standards. It is of course obvious that this freedom for site specific decision making has to be surrounded by some hard boundaries, which are set for instance by the acceptability of human health risks. Furthermore RBLM decision-making is intended to be transparent so that it can be democratically applied.

Another important aspect of RBLM is the spatial dimension implied by the word “land”. This opens the possibility for a hierarchical management system based on different spatial units of land. For instance a farmer or industrial landowner can be regarded as the manager of his land within a legal framework or a mandate given by a higher level authority like a municipality or a province. Because the soil environment has its own natural structure and intrinsic properties it would be beneficial to take also natural boundaries between different soil situations into account in the design of hierarchical soil management systems. This becomes more obvious when the close relation between soil and water is considered.

It has to be recognized that RBLM, as developed by CLARINET, is primarily focussed on risk management of contaminated land. However it is also a framework both for addressing uncertainties, and for integration of wider environmental, spatial planning and water management issues. These will be relevant for the prevention of future land degradation.

Preventing land and water resources from degradation requires comprehensive knowledge about the significance of damage and about the connection between the pressures on soil (or land) and the resulting effects. This is a complex issue and the current level of scientific knowledge is very limited.

The RBLM approach offers a practical way forward to identify and assess the measurable effects from existing land degradation. It can also be used to evaluate the overall effect of counter measures or to compare the effects of different counter measures. Experience from development of strategies for managing contaminated land may greatly contribute to wider management strategies to prevent soil problems.

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[8] European Commission (2001) EC Communication on the sixth environment action programme of the European Community *'Environment 2010: Our future, Our choice'*. Brussels, 24.1.2001, COM (2001) 31 final

[9] European Commission (2002) EC Communication *"Towards a Thematic Strategy for Soil Protection"*. Brussels, 16.4.2002, COM (2002) 179 final.

THE WAY FORWARD

To put the RBLM concept into practice, action therefore needs to take place on three main fronts:

(1) in continued research to improve the knowledge base and develop tools to support the emerging areas of European policy which are affected by contaminated land;

(2) in improving practice by the transfer of knowledge and information to a range of groups; and

(3) in integration of policy approaches.

CONCLUSION

Environmental priority setting for policymaking and regulation has often considered water and air before land. Land issues - such as contamination, land use, soil protection - are still considered in different compartments and, to some extent as a result, as a series of ad hoc problems. Technical solutions have often addressed a narrow perspective; in particular, the long-term value of the land as an environmental resource or the wider impacts of particular technologies have not been considered.

As experience has shown in other environmental fields, a narrow problem-oriented approach will not automatically lead to a sustainable use of environmental resources. The total environment, including soil and water, has to be managed in a sustainable way.

Better decisions about the solutions of contaminated land problems can be made if there is clear interaction and integration of the management of contaminated land, of land use planning, and of wider environmental protection controls.

The Risk Based Land Management concept of the CLARINET concerted action is intended to be a step forward towards an integration of sustainable soil quality, protection of water and land use management in environmental policy.

CLARINET's vision is to see a change in social and political attitudes away from a negative perception of contaminated land towards that of positive shared action to conserve and enhance the soil and water resources.

REFERENCES

CARACAS - Concerted Action on Risk Assessment for Contaminated Sites in Europe (1996-98): http://www.caracas.at

CLARINET – Contaminated Land Rehabilitation Network in Europe (1998-2001): http://www.clarinet.at

Ferguson C. (1999) *Assessing Risks from Contaminated Sites: Policy and Practice in 16 European Countries;* Land Contamination & Reclamation, 7 (2) pp. 33, EPP Publications. Available on http://www.caracas.at

Vegter J.J., Lowe J., Kasamas H. (2002) *Sustainable Management of Contaminated Land: An Overview* Austrian Federal Environment Agency 2002 on behalf of CLARINET. Available on http://www.clarinet.at

ANNEX: THE WORK OF CLARINET

CLARINET has been a concerted action on contaminated land funded under the European Commission 4th Framework Programme for Research and Technological Development. It developed as part of a wider history of emerging collaboration and international exchange on contaminated land. In particular it builds on the work of CARACAS[10] and has links with other networks and organisations.

The overall aim of CLARINET has been to identify efficient ways to deal with contaminated land without compromising public health and water quality, business confidence in the benefits of land regeneration, or the sustainable use of land. As a focussed network, it has promoted partnership between the EC and member states, between the 20 or more countries who send representatives and between many different stakeholders (including Government Ministries and Agencies, industry, and scientists). It is multidisciplinary and has aimed to be a catalyst between different perspectives. It has contributed to continuing research and technological development programmes both under the EC 5th Framework Programme and beyond, and at national level.

CLARINET has concentrated its work on a number of key areas of relevance to find solutions to contaminated land problems. Working groups have covered:

- Impact of contaminated land on water resources
- Brownfield redevelopment
- Human health
- Ecological health related to land uses and functions
- Remediation technologies and techniques
- Decision support
- Collaboration of R&D programmes in Europe.

All of these groups have produced specific outputs which are available on the CLARINET Website

http://www.clarinet.at

[10] CARACAS - Concerted Action on Risk Assessment for Contaminated Sites in Europe (1996-98): *http://www.caracas.at*

AN INTEGRATED REGULATORY APPROACH TO RISK ASSESSMENT AND RISK MANAGEMENT FOR POLLUTED GROUNDWATER

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SUMMARY

The regulatory regime for contaminated land and groundwater in the UK is risk-based. Indeed, the definition of Contaminated Land in UK law requires the presence, or likelihood, of pollution or significant harm before affected land meets the statutory test of being Contaminated Land. In dealing with contamination, a risk-management approach is used that also requires the consideration of wider land-use planning priorities, the costs and benefits of remedial action, and the goal of achieving sustainable development. A parallel risk-based framework is adopted for polluted groundwater.

The key to making good decisions in relation to assessing and then managing risks from polluted groundwater is a sound understanding of the site / aquifer and the physical, chemical and biological processes occurring therein. The development of a conceptual model, which draws together details about the site, scientific understanding on relevant processes in the subsurface, and public / private priorities and objectives for land and water-use planning is an essential tool for understanding the problem in the widest context.

The risk-assessment process adopted for contaminated groundwater follows a tiered structure. A simple conceptual model is developed from desk study and site reconnaissance. This conceptual model is then used as the basis for designing a site investigation programme – the sampling being done to test assumptions within the conceptual model as well as to develop it further. The Environment Agency has developed a package of tools to aid this tiered approach.

The objectives of remediation are to remove unacceptable risks to health or the environment. Effectiveness, durability and practicability, the likely costs and benefits and contribution to achieving sustainable development are all considered in selecting a remedial option. The Agency has developed methods for assessing the likely costs and benefits of groundwater remediation that take account of societal (external) costs rather than just the private costs to a developer or landowner. Using these approaches in tandem it is possible to find an optimal level of remediation and thus the best 'environmental balance' achievable using remedial techniques.

This paper describes the integrated risk assessment and risk management processes for contaminated groundwater in the UK, with emphasis on the tools and methods developed. It explains the importance of a conceptual understanding (or model) to all tiers of risk assessment and subsequent risk management.

INTRODUCTION

The Environment Agency (for England and Wales) has duties to protect controlled waters (including groundwater) and to ensure that its actions contribute to the goal of achieving sustainable development. With respect to contaminated groundwater, the Agency has adopted a risk-based approach to its assessment and management, in line with government recommendations (DETR *et al*, 2000; DEFRA & EA, 2003).

The key to effective risk assessment and risk management is a sound understanding of the scientific processes that affect contaminant transport in the environment, and the mechanisms by which receptors can be exposed to those substances. This understanding is termed a conceptual model and is the cornerstone around which risks are assessed and a risk-management strategy developed.

The risk-assessment process adopted for contaminated groundwater follows a tiered structure. A simple conceptual model is initially developed from desk study and site reconnaissance information.

This conceptual model is then used as the basis for designing a site investigation programme – the sampling being done to test assumptions within the conceptual model as well to develop it further. It is essential to be clear why the risk-assessment is being undertaken, that is to say, which questions the assessor is aiming to answer. The data and information collected should aim to reduce uncertainty in those aspects to which the particular decision is most sensitive. Consequently, the conceptual model should be built-up by collecting information on the processes and conditions that most affect the fate and behaviour of hazardous substances within each as part of the source-pathway-receptor linkage.

The Environment Agency has developed a package of risk-assessment tools to aid this tiered approach, from screening level Groundwater Vulnerability maps (NRA, 1995a) and Source Protection Zones (NRA, 1995b), to simple analytical models using deterministic and probabilistic methods (Remedial Targets methodology (EA, 1999) and ConSim (EA, 2003) respectively). Finally, where it is necessary, complex risk assessment methods are used and the Agency has developed new code to better simulate variable conductivity and storage with depth through an aquifer - conditions commonly found in UK aquifers (EA, 2002; EA & BGS, 2002).

Alongside methods for groundwater, techniques for assessing the risks to human health from chronic and acute exposure to contaminants, risks to ecosystems and property have been developed. The Contaminated Land Exposure Assessment model (CLEA), for example, is the recently launched approach for assessing chronic risks to human health, which should be integrated into whole-site decisions (DEFRA & EA, 2002; Martin *et al*, 2003).

RISK ASSESSMENT AND MANAGEMENT FRAMEWORK

The UK framework for risk assessment and management is shown in figure 1. The main stages within each tier of ***risk assessment*** are:

1. ***Hazard Identification***: Identification of contaminant sources, pathways and receptors, taking into account the actual or intended use of the site and its environmental setting.

2. ***Consequence Assessment***, which incorporates the three stages of identifying possible consequences, and assessing the likely magnitude and likelihood of those consequences. This process requires consideration of the plausibility of source-pathway-receptor linkages and determination of the potential for adverse impacts.

3. ***Risk Estimation***: Estimation of the significance of any risk(s) that identified receptor(s) will suffer adverse effects if they come into contact with, or are otherwise affected by, contaminant sources under defined conditions. Risk estimation taking information on the likelihood, nature and extent of exposure (or of other hazardous conditions) and making a judgement on the significance of any adverse consequences that could occur. Note that the expression of risk may be in qualitative (i.e. the likelihood of serious pollution is low or high) or (more rarely) quantitative terms.

Following the assessment of risk the results are taken forward to decide whether risk management (remedial) actions are necessary to reduce any unacceptable risks, and, if it they are, what the best method is. This ***Risk Management*** incorporates an evaluation of the need for risk management action (i.e. risk reduction or control measures) having regard to the nature and scale of risk estimates, any uncertainties associated with the assessment process and, where further action is required, the objectives, and broad costs and benefits of that action.

The first three processes take place within each of the tiers shown. However, the level of resource and effort expended at each tier increases in response to the significance of the risk or uncertainty in the decision. Where only insignificant risks are identified, or the outcome of a particular occurrence can be predicted with a high level of certainty, a robust decision may be made with minimal data at Tier 1. As the severity of possible pollution or harm increases, or the prediction is increasingly uncertain, the assessment process moves to higher tiers, which also necessitates additional data collection and analyses.

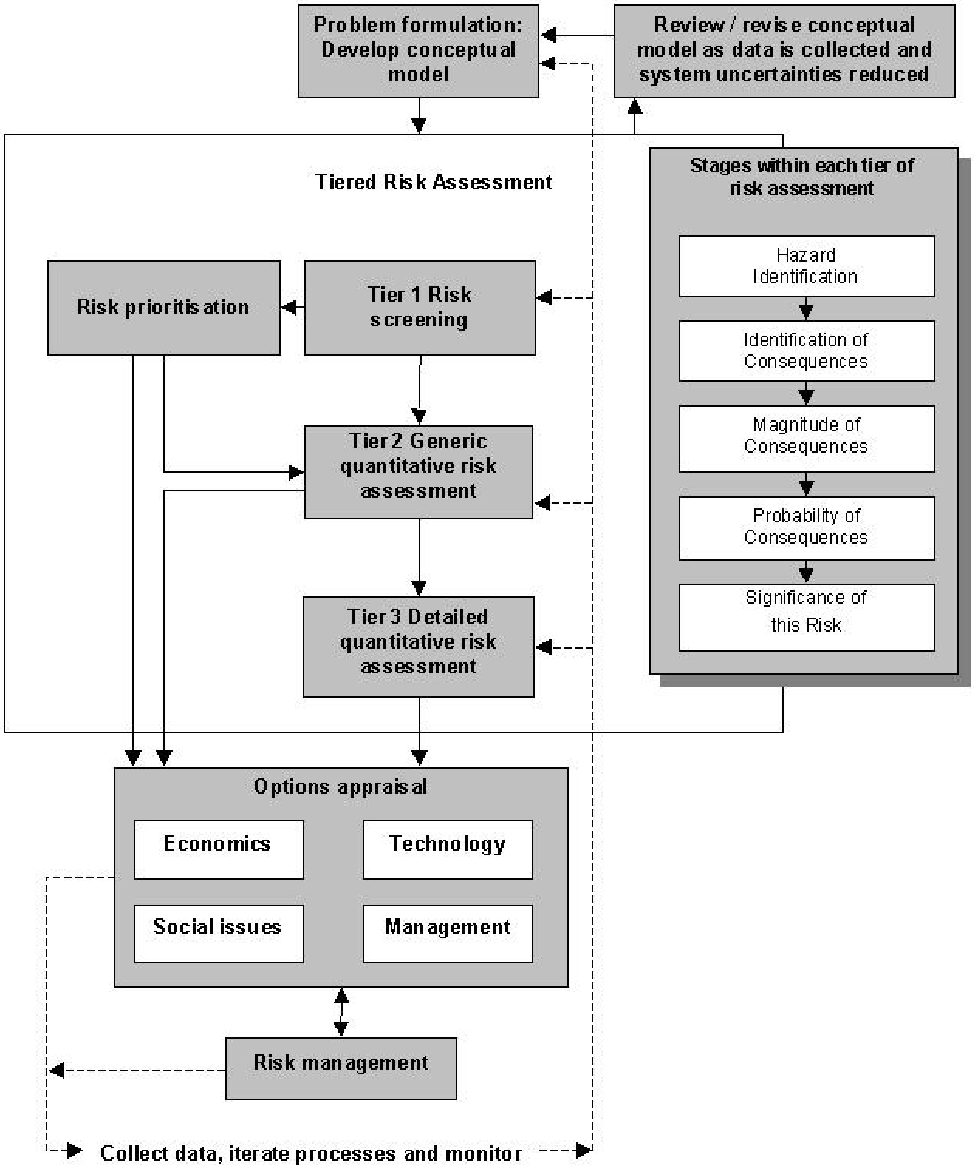

Figure 1. A framework for environmental risk assessment and management (based on DETR, EA and IEH, 2000)

The following sections describe the methods and tools used at different risk assessment tiers to test and refine the conceptual model of the site and its surroundings, and to understand the key processes that influence the ultimate decision on the significance of pollution risks.

TIER 1 – RISK SCREENING

The initial tier (risk screening) largely relies on a desk-based study and an initial site reconnaissance visit, without detailed sampling or intrusive investigation to establish whether there are conditions or circumstances on a site that could give rise to unacceptable risks. Its aim is to allow the assessor to develop an initial understanding, or conceptual model, of the site and its surroundings, which will provide the basis for subsequent stages of assessment. It is essentially qualitative in terms of both information collation and impact prediction. Where risk screening indicates that there are very unlikely to be unacceptable risks (e.g. because there are no identified receptors in the vicinity of a contaminated site), then risk screening facilitates prioritisation of further action, both in terms of its urgency and its detail.

The development and continued refinement of a conceptual model is an important concept that is fundamental to the successful and robust assessment of risks (EA, 2001). The conceptual model should allow the assessor to visualise the site, any contamination and the mechanisms by which pollutants might migrate, or receptors be exposed. The conceptual model should evolve throughout the risk assessment and management process. It should never be developed and then ‘left on a shelf’ unchanged despite the gathering of additional data and information. The process is iterative and at each stage of the assessment the conceptual model should be revisited to test whether previous assumptions remain valid and whether the collection of new information supports, or requires amendment of, the model.

With respect to the assessment of risks to groundwater, it is important to remember that the greatest risks are normally associated with contamination that is in a mobile, or leachable form. Chemical analysis of potentially contaminated soils often focuses on the concentration of a contaminant as a ‘total contaminant concentration’. There are instances where this is important information for the consideration of risks to water quality (e.g. material on riverbanks, in flood plains, or in highly fissured aquifers). However, in most instances it is more important to assess the fraction of contamination that is soluble in water, and have regard to the fact that some contamination may have by-passed the soil that has been sampled. At this early stage, consideration should be given to the potential for pollution of water, by considering the physical and chemical properties of those contaminants that are most likely to be present, given the previous uses of the site. By considering these issues early, it is possible to focus the site characterisation and analytical testing on the areas and substances most likely to be significant (i.e. to test the conceptual model where uncertainties and/or parameter sensitivities are greatest).

The key tools used for screening risks to groundwater from polluted sites are set out in the *Policy and Practice for the Protection of Groundwater* (EA, 1998). It introduces concepts of groundwater vulnerability and source zone protection as a basis for prioritising both protective and remedial actions for groundwater. All geological strata in England and Wales have been divided into three classes; Major, Minor and Non-aquifer on the basis of their hydrogeological properties. The classification essentially reflects the strategic water resource value of different geological formations, but should be subject to local consideration of local hydrogeological conditions.

Major Aquifers are described as ‘highly permeable formations usually with the known or probable presence of significant fracturing. They may be highly productive strata of regional importance, often used for large potable abstractions.’

Minor Aquifer are defined as strata being ‘fractured or potentially fractured but with high intergranular permeability, or variable porous/permeable but without significant fracturing. They generally only support locally important abstractions, or baseflow to watercourses’.

Non-aquifers are formations with negligible permeability that are generally regarded as not containing groundwater in exploitable quantities.

Superimposed over the aquifer classification, are data on soil and drift geology that take account of the leaching potential of the soils. Where an aquifer is overlain by a thick clay soil, the potential for contaminants to reach the groundwater is reduced. Combined, these produce seven classes of aquifer vulnerability. These are shown in figure 2, which is a portion of one of the 53 maps at 1:100,000 scale covering England and Wales.

If it is found, for example, that the hydrogeology around a contaminated site is such the presence of those contaminants does not pose a significant risk to the water environment then further resources would be directed towards other, more sensitive sites. This could be, for example, because it is a low permeability formation with no water resource value (a Non-aquifer) and there are no dependent surface waters or ecosystems locally. However, where it is identified that the site is underlain by a sensitive aquifer, such as a Major or Minor Aquifer, then it would be prioritised for further investigation and assessment.

A similar approach can be taken for screening potential sources of contamination. Rather than investigate all contaminant sources with equal priority, emphasis is placed on those sites that had activities that can give rise to polluting and mobile substances, and site characterisation should be focussed on particular areas of concern taking account of the historic use and layout of each site.

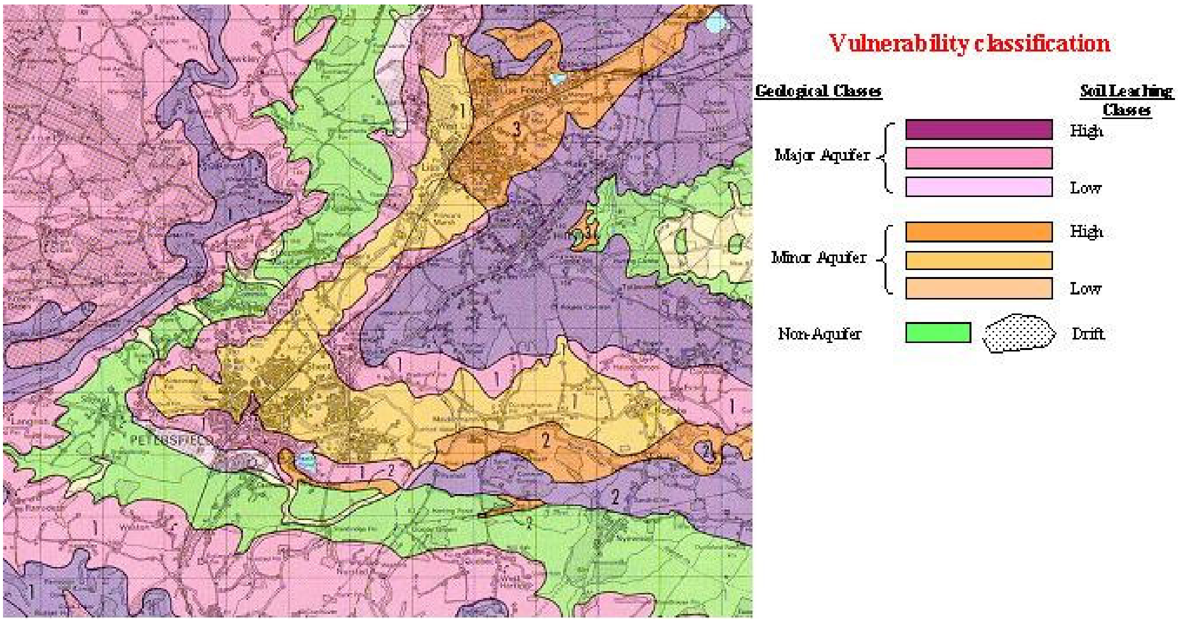

Figure 2. Example Groundwater Vulnerability map, at 1:100,000 scale of area around Petersfield

The second basis for assessing the sensitivity of groundwater is the proximity of the site to a groundwater abstraction point, typically a borehole, well or spring. The catchments of about 2000 public water supply abstractions and other large or sensitive sources (e.g. brewery abstractions) have been modelled and had Source Protection Zones published. Three zones are produced for each abstraction: Inner Source Protection Zones (SPZ I); Outer Source Protection Zones (SPZ II) and total catchment zones (SPZ III) (see figure 3).

Modelled Source Protection Zones are based on the predicted travel time of groundwater within the saturated aquifer to an abstraction point. The Inner Zone (SPZ I) is based on a 50-day travel time and is a small zone immediately around the borehole. The 50-day period is selected to allow for degradation of typical microbiological contaminants in groundwater, such as those in discharges of sewage effluent. The Outer Zone (SPZ II) is based on a 400-day travel time and is designed to provide protection of the borehole from reasonably degradable chemicals. The entire catchment of the abstraction (SPZ III) indicates the extent of the aquifer that contributes water to the abstraction.

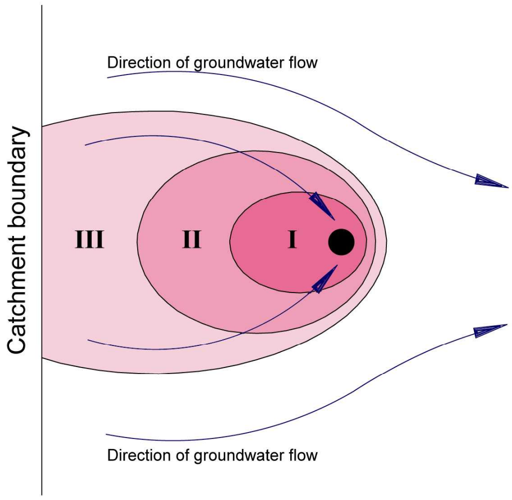

Figure 3. Schematic Source Protection Zones (SPZ I, II and III). Abstraction point indicated by •

TIER 2 – GENERIC QUANTITATIVE RISK ASSESSMENT

The second tier of risk assessment uses generic risk assessment criteria to establish whether, on the basis of conservative assumptions, there is an unacceptable risk. In the case of contaminated groundwater this normally relies on comparison of groundwater monitoring data or soils leachability testing results with relevant water quality standards and guidelines.

Direct comparison with water quality standards assumes there is no dilution, attenuation or retardation of contaminant concentrations between the source (soluble/mobile soil contaminants) and the receiving water body. It fails to recognise that there are any attenuation processes between the contaminant source and the point at which the standard strictly applies (e.g. a drinking water standard applies at the point of supply – the tap – not the aquifer from which is abstracted). As a result, direct comparison is invariably the most conservative of the available assessment approaches. Subject to the sufficiency of the data, provided the concentrations of soluble/mobile contaminants do not exceed the relevant generic assessment criteria, it can be concluded that the substances pose no significant risks to the receiving water body, or users of that water. Where the concentrations of soluble/mobile contaminants exceed the relevant generic assessment criteria, further action, being either risk remediation or more complex risk assessment that more accurately represents the conceptual model, is warranted. Generic assessment criteria typically used in the UK are tabulated in Table 1, below.

To reach a judgement at tier 2, data is needed on the concentration of pollutants in the affected groundwater, and on the local use of the groundwater for human abstraction, or support of other environmental systems. This requires refinement of the conceptual model produced previously through more detailed site characterisation and assessment, usually on the basis of further desk-based research and limited exploratory site investigation.

Table 1. Possible generic assessment criteria for use in groundwater risk assessment

Contaminant property	**Technical issues to consider**	**Relevant generic assessment criteria (water quality standards)**
Poisonous	Potential to cause harm to living organisms (including humans) by exposure to toxins. Implies requirement to consider relevant dose	EU/UK Drinking Water Standards; WHO (Health) guideline values; EU/UK Environmental Quality Standards
Noxious	Potential to cause nuisance or harm, e.g. by taste, odour or discolouration	WHO (Appearance, Taste & Odour) guideline values; Taste and odour threshold data
Polluting	Potential to cause environmental detriment (to water quality and ecosystems)	Environmental Quality Standards; Presence of solid waste
Solid waste matter	Amenity and aesthetic detriment or harm to aquatic organisms (e.g. by attrition of fish gills or reduced light to aquatic flora)	Suspended solid threshold limits

Assessment methods of contaminant leaching characteristics, such as recent CEN methods, and of sorption characteristics (EA, 2000a) are valuable for understanding the likely mobility of contaminants, and for deciding whether substances with hazardous properties also pose a possible risk to receptors because they are able to migrate to a point at which exposure of those receptors could occur.

TIER 3 – DETAILED QUANTITATIVE RISK ASSESSMENT

At tier 3 more complex tools are used to represent or simulate the conceptual model, such that site-specific risks are quantified. This requires greater data collection to reduce uncertainties and refine the conceptual model.

This phase should address the nature, likely location and behaviour of contaminants and possible interactions with defined receptors, with the aim of establishing quantitatively the nature of a linkage between potential *Sources, Pathways and Receptors*. A preliminary indication of the potential for chronic and short term risks to health and the environment can also be formed, assuming information is available on the nature, concentration and location of contaminants.

Risk estimation approaches, such as the Remedial Targets methodology (EA, 1999) and relatively simple models including ConSim (EA, 2003) may be used to predict the impact of a contaminant source on the receptor. A variety of different outputs can be obtained depending on the techniques used.

Simple models provide some scope for varying input values according to known or assumed site conditions thereby avoiding some of the inherent conservatism associated with the direct comparison approach. For example, they permit dilution and attenuation effects to be taken into account in establishing the concentration of contaminants likely to be present at a receptor located at some distance from the contaminant source. If the output of simple conservative models indicates that the whole or part of the site is likely to pose unacceptable risks to the water environment, assessors again have the option of further refining risk estimates using complex modelling techniques or evaluating the best form of remedial action. Simple models and analytical tools often only provide a 'snapshot' of the system and do not provide predictions over time or assessment of time-variable factors. To include this in an assessment, more complex tools are normally required.

Complex models are used to describe the fate and transport of contaminants in the environment, particularly where predictions are needed in both space and time. This approach allows for a high degree of site specificity since a large number of the input values can be varied to reflect actual or likely site conditions. However, it requires specialist expertise and extensive data on the characteristics of the source, pathway and receptor.

Noting the complexity of UK hydrogeological systems the Agency has developed code to allow better representation of the UK aquifer conditions. Recent work (EA, 2002; EA & BGS, 2002) allows simulation of vertical variation in hydraulic conductivity through an aquifer for use in regional numeric flow and contaminant transport modelling applications.

Assessors should select a model or analytical technique which is capable of simulating the conceptual model developed, is capable of producing usable results that are sufficiently accurate to allow necessary decisions to be made, and is appropriate to the scale of the problem and the quality of the available data. Assessment techniques may vary from simple comparison, through deterministic and probabilistic methods based on analytical solutions, to complex numerical hydrogeological models.

RISK MANAGEMENT

If it is established that the presence of contamination is such that it causes an unacceptable risk to health or the environment, it is necessary to undertake some form of remedial action to mitigate those risks. Within the UK's risk-based framework, the goals of remediation are to remove unacceptable risks, and consequently the terms remediation and risk-management are directly interchangeable. Remediation includes any action that leads to reduction or control of risk, not simply traditional engineering or process-based technologies that 'clean-up' contaminated media.

The conceptual model developed previously for risk assessment purposes is equally valuable in developing a risk management strategy, since information on site-specific conditions and any natural contaminant flux-reducing processes are also necessary when selecting the best remediation method. This approach is illustrated by guidance on monitored natural attenuation (EA, 2000b), which aims to crate a seamless decision-making process around the site conceptual model from initial identification of contamination problems, to selection of the optimal remedial approach.

Within the UK framework a number of aspects must be considered during selection of remedial options:

- effectiveness of remedial action;
- durability of action;
- practicability of action;
- likely costs and benefits;
- other management and social issues.

Within the three central decision processes indicated in figure 4, (for human health, water quality and other receptors), a tiered approach is taken so that the level of resource and complexity of decision-making tool used is proportionate to the broad level of risk associated with each hazard. The tiered structure shown in figure 1 could be shown within each of these three process steps.

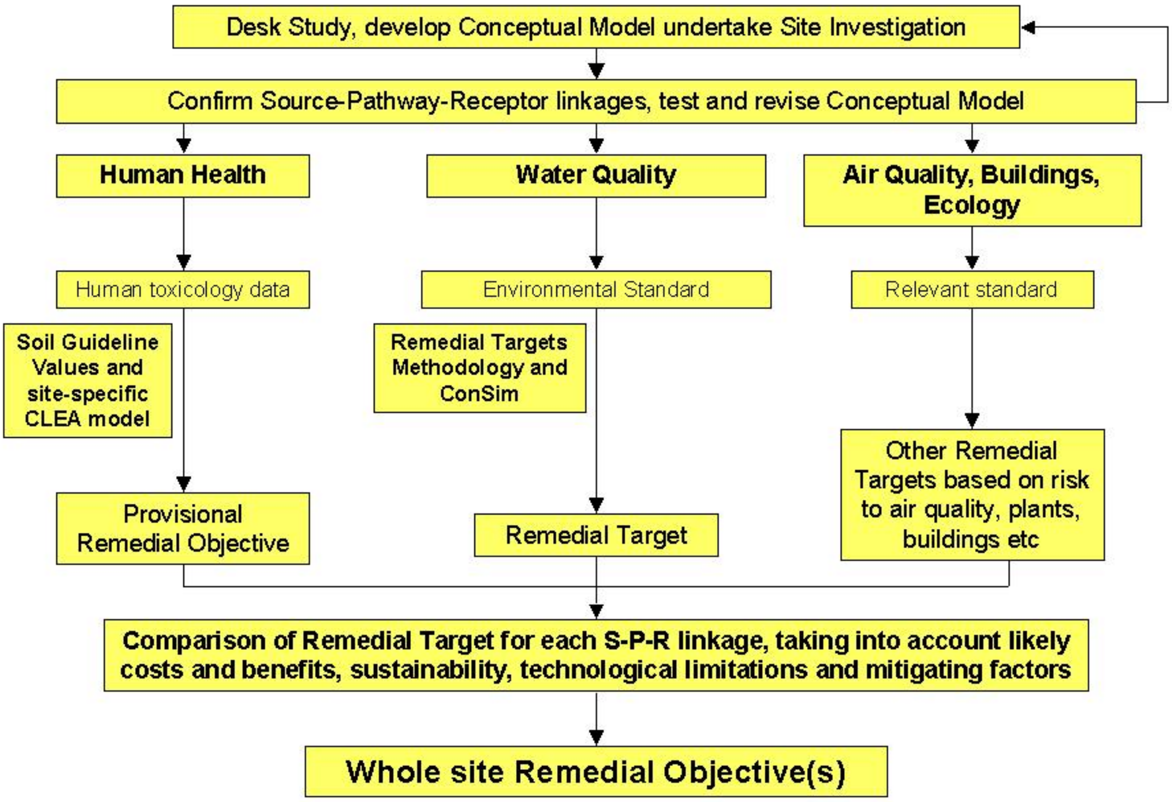

Figure 4. Integration of assessment for all receptors is key to whole-site decision making

Identifying the best environmental balance is a key factor in ensuring remedial works contribute to sustainable development. For example, in some jurisdictions attainment of maximum concentration limits (MCLs) similar to drinking water standards across aquifers (including the source areas within contaminated sites) is a mandated goal, regardless of the risk-reduction this brings, or the environmental damage that may be caused by undertaking a long energy-intensive remediation. It is often stated that in remediation 80% of the benefit can be achieved with 20% of the financial costs, and the remaining 20% benefit can only be realised by spending 80% of the cost. The same argument can be made with to respect environmental costs of remediation, caused, for example by burning fossil fuels to operate generators or to undertake thermal treatments. Is it 'worth' running a diesel generator for a pump and treat scheme to reduce pollutant concentrations from, say, 50µg/l to an MCL of, say, 10µg/l if that means releasing carbon dioxide and other pollutants into the atmosphere over a number of years, with consequent impacts on the local and global atmosphere?

While the problem holder may be principally concerned with minimising their private financial costs, the Environment Agency's goal is to maximise societal benefits, which implicitly includes minimising environmental damage, both from the original groundwater pollution, and from any remedial works proposed (EA, 2000c).

CONCLUSIONS

This paper describes the Environment Agency's approach and tools for risk-assessment and management, with an emphasis on attaining risk-based remedial solutions that balance the environmental benefits achieved with their costs, with the ultimate goal of selecting a sustainable, environmentally-optimal solution to the problems of polluted groundwater.

The Agency's approach follows a continuous processes that relies, at its core, on understanding the site and processes acting on contaminants, as described and documented within a conceptual model. This conceptual model is live, rather than produced and reported once, and should be challenged and tested as knowledge and data increase through the risk assessment process. It is key that any assumptions incorporated within the conceptual model are reviewed as new information comes available, so that decisions are made on the basis of best knowledge.

REFERENCES

DETR, Environment Agency & Institute for Environment and Health, 2000. *Guidelines for environmental risk assessment and management*. DETR (now DEFRA), London.

DEFRA & Environment Agency, 2002. *Assessment of risks to human health from land contamination: An overview of the development of soil guidelines values and related research*. Environment Agency R&D Publication CLR 7.

DEFRA & Environment Agency, 2003 (in prep). *Model procedures for the management of land contamination*.

Environment Agency, 1998. *Policy and practice for protection of groundwater*. (2nd edition). The Stationery Office, London.

Environment Agency, 1999. *Methodology for the derivation of remedial targets for soil and groundwater to protect water resources*. Environment Agency R&D Publication 20, Bristol.

Environment Agency, 2000a. *CEC and K_d determination in landfill performance evaluation. A review of methodologies and preparation of standard materials for laboratory analysis*. Environment Agency R&D Technical Report P340, Bristol.

Environment Agency, 2000b. *Guidance on the assessment and monitoring of natural attenuation of contaminants in groundwater*. Environment Agency R&D Publication 95, Bristol.

Environment Agency, 2000c. *Costs and benefits associated with remediation of contaminated groundwater: A framework for assessment*. Environment Agency R&D Technical Report P279, Bristol.

Environment Agency, 2001. *Guide to good practice for the development of conceptual models and the selection and application of mathematical models of contaminant transport processes in the subsurface*. National Groundwater & Contaminated Land Centre report NC/99/38/2. Solihull, UK

Environment Agency, 2002. *Enhancement to MODFLOW: Variations in hydraulic conductivity and storage with depth*. National Groundwater & Contaminated Land Centre report NC/00/23. Solihull, UK

Environment Agency, 2003. *ConSim release 2: Contamination impact on groundwater. Simulation by Monte Carlo method*. Environment Agency R&D Publication 132. Golder Associates, Nottingham.

Environment Agency & British Geological Survey, 2002. *Steady-state particle tracking in the object-orientated regional groundwater model ZOOMQ3D*. NGWCLC report NC/01/38/2. Solihull, UK

Kearney, 2003. *Management of land contamination: The UK framework*. ConSoil 2003, 8th International FZK/TNO conference on contaminated soil, Gent.

National Rivers Authority, 1995. *Guide to groundwater protection zones in England and Wales*. NRA (now Environment Agency). The Stationery Office, London.

National Rivers Authority, 1995. *Guide to groundwater vulnerability mapping in England and Wales*. NRA (now Environment Agency). The Stationery Office, London.

Martin, I., Duarte-Davidson, R., Barraclough, D., Woolgar, P. & Earl, N, 2003. *Assessing risks to health from land contamination from a UK perspective*. ConSoil 2003, 8th International FZK/TNO conference on contaminated soil, Gent.

SAFE MANAGEMENT OF POLLUTED SEDIMENT-DERIVED SOILS IN THE SCHELDT BASIN

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Introduction

In this paper polluted sediment-derived soils (SDS) are focused on. First a general description of this source of soil pollution is given and a classification of the current situation is proposed. A summary of the actual risks is presented and then we give an overview of the desirable and feasible management options to reduce potential risks. Alluvial soils are used as a reference situation for evaluation of pollution status and soil functioning of sediment-derived soils. We searched for an adapted function for SDS. In each step we used the results of a case-study along the Scheldt river as an example. This study area, called 'Merelbeekse Scheldemeersen' is situated on the right bank of the Upper Scheldt just upstream from the intersection with the Ring Canal (Fig. 1). The Upper Scheldt was already strongly regulated in the 19th century (e.g. dike constructions) to allow for shipping transport and winter irrigation of the lower parts (van Strydonck & de Mulder, 2000). The 'Merelbeekse Scheldemeersen' area is strongly human influenced: in the 19th century meanders were cut short. The area was also used for superficially clay reclamation for brick construction resulting in the lowering of the soil profile. Some 7 ha of these low areas were used for dredged sediment disposal (Vandecasteele et al., 2002a). From 1957 on the Upper Scheldt was canalised in several phases to allow for shipping transport up to 1350 ton. For these canalisation works in the study area, 38 ha of unpolluted landfills with infrastructure spoil were constructed mainly in the wetter parts of the study area. For recent dredging works, landfills outside the study area were used. In the area also 5 ha of abandoned household waste dumpsites were mapped. The area is thus characterised by a varied relief.

I. Problem identification

Sediment-derived soils can be a consequence of natural processes such as overbank sedimentation or human interventions in river characteristics, with the disposal of dredged sediments in the alluvial plains as important feature (Vandecasteele et al., 2002a). Two problems are encountered when sediments are considered: on one hand the high sediment load of rivers reduces water discharge and the shipping transport capacity and on the other the sediment quality is very low due to pollutants and high nutrient contents. Especially in the Flemish region both sediment quality and quantity is problematic due to intensive land-use, high urbanisation and industrialisation, and poor sewage treatment. An important feature of the sediment substrates is their initially high carbonate content and the resulting high buffering capacity against acidification and the subsequent low leaching potential for heavy metals.

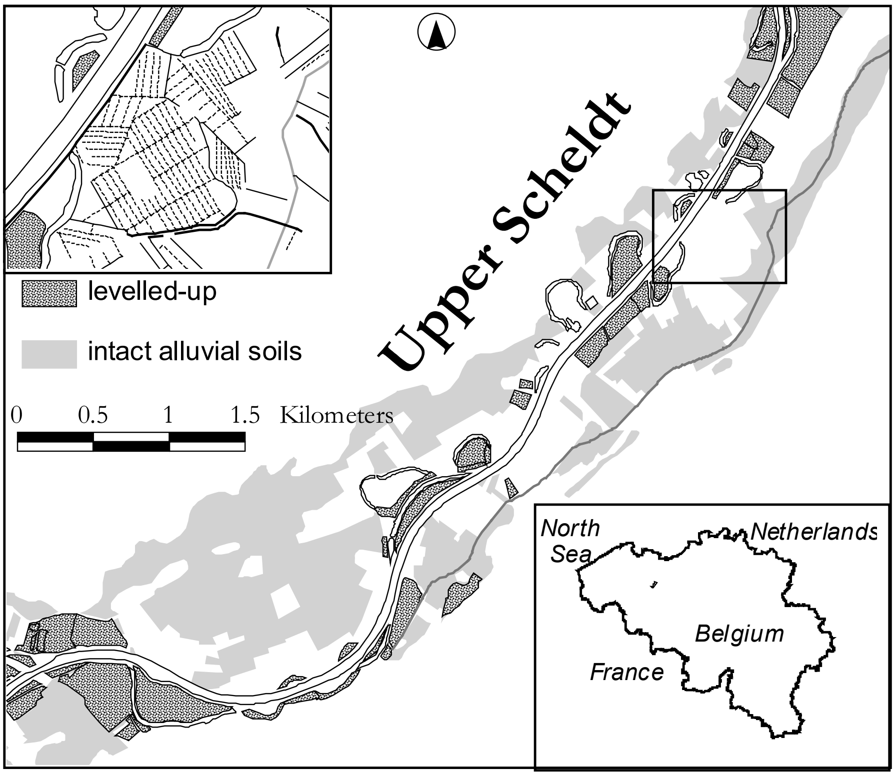

Figure 1. Study area with the lower inset showing the position of the area, and the upper inset showing the central part ("Reymere") were wetland construction and restoration is proposed.

We thus consider both spontaneously formed overbank sedimentation zones (OSZ) and "human-made" dredged sediment-derived soils (DSDS). The first category of soils is characterised by a low sediment layer thickness, a strong correlation between pollution level and distance to the river banks and an overall high variability and susceptibility to floodings. The DSDS generally split up in two groups, with on one hand the recent DSDS being confined disposal sites with a high layer thickness and thus a high surface use efficiency, and a range of protecting measures. On the other hand, we found a lot of older DSDS, characterised by low sediment layer thickness and mostly situated in lowland areas protected as nature areas for spatial planning goals. Especially the problems of the latter group are rather complex, as these sites are not generally known as DSDS and areas are planned tot be used as normal alluvial soils for nature protection and integrated water management with inclusion of wetlands in river processes.

Other categories of SDS not discussed here are tidal marshes, and stormwater wetlands. Tidal marshes are an example of a system in tight contact with the river and a situation in which human interventions are unrealistic. Monitoring of processes on tidal marshes is a valuable tool for a better evaluation of processes on DSDS and OSZ. A new development in integrated water management is the creation of stormwater wetlands, in which overbank sedimentation of polluted sediments may be expected to occur.

Study area

The study area (Fig. 1) was subdivided in the part used for clay excavation (54 points) and the unaffected alluvial soils (9 points). In Fig. 2 the Cd concentration and the sand and $CaCO_3$ content are given as function of the distance tot the river. The highest values for Cd and $CaCO_3$ were measured closest to the river. A similar pattern was observed for P and S. The sand contents were lowest in the part adjacent to the Scheldt. The values for the heavy metals, P, S, OC and N are clearly lower in the soil samples of the unaffected alluvial soil (Table 1). In Fig. 2 it is clearly shown that the soil quality of the unaffected alluvial soils is generally better than the superficially excavated soils. On the other hand it is observed that the soil pollution in the area used for clay reclamation is highest in a strip of 100-150 m adjacent to the dike, but the relation between pollution level and distance to the river is not straightforward as both high and low concentrations are measured close to the river.

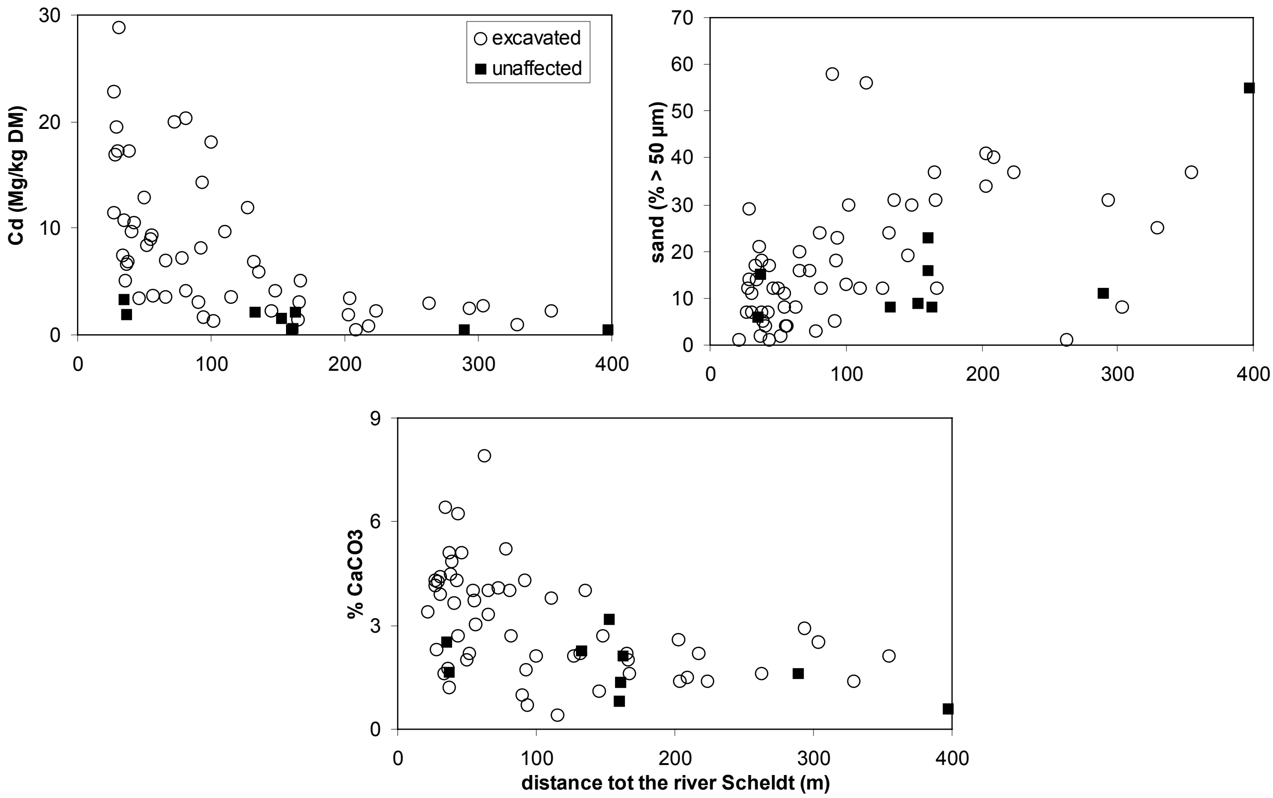

Figure 2. Cd-concentrations, sand and $CaCO_3$ contents (%) for the soil samples of the excavated and unaffected alluvial soils in the study area in relation to the distance to the Scheldt (bird's-eye view).

II. Management objectives

Large areas affected by the presence of sediment-derived soils are protected as nature area. Both nature management and environmental management objectives must be combined in a safe, risk-based management objective. We consider 2 reasons for risk-based management of polluted SDS: (1) when an alternative management for polluted sites is proposed e.g. for nature rehabilitation goals, an increase in ecotoxicological risks must be avoided and (2) selecting an appropriate risk-reducing management for polluted sites as an alternative for expensive sanitation operations.

When a management objective for nature development on polluted SDS is proposed, both risks of pollution and feasibility of the selected target must be considered. Three aspects can limit the feasibility: (1) SDS and especially DSDS are levelled-up and thus have a changed hydrology and sometimes another soil texture, (2) SDS are rich in nutrients and thus can limit the development of certain species and stimulate another vegetation type, and (3) pollution can result in toxicity for target species. The first aspect is a rather hard condition which is also visually observable in contrast with the remote eutrophic and polluted nature of the SDS which might be more limiting for the species. First we must consider the substrate characteristics and the relative suitability as rooting medium or habitat for plants and soil organisms. In the Netherlands, an evaluation of toxicity for target species typical for the selected habitat target is used. When nature management goals can not be met due to pollution, remediation measures must be considered (Worm et al., 1998).

Table 1. Descriptive properties for the A-horizon for both excavated (58 sampling points) and unaffected alluvial soils (8 points)

	excavated soils			unaffected alluvial soils		
	Min.	Median	Max.	Min.	Median	Max.
Cd (mg/kg DM)	0.5	7.1	51.1	0.5	1.5	3.3
Cr (mg/kg DM)	32	181	1107	45	75	134
Zn (mg/kg DM)	79	774	2311	72	146	313
clay (%)	11	28	42	16	23	33
silt (%)	18	57	67	29	63	70
S (mg/kg DM)	391	1107	2238	286	522	860
N (%)	0.3	0.4	0.8	0.2	0.3	0.5
$CaCO_3$ (%)	0.4	2.7	7.9	0.6	1.7	3.2
OM (%)	2.7	8.3	14.8	2.3	5.3	8.6
EC (µS/cm)	117	210	942	73	146	252

An important choice is the scale of the target area. In a first approximation of an area, one can require that each single part should fulfil all the prerequisites for optimal habitat function and should allow optimal biodiversity and sustainable habitat development (van Straalen & Denneman, 1989). From a more moderate point of view, one can state that the polluted SDS must guarantee the save disposal of pollutants and may not hinder the habitat functioning of the whole area, both in the current situation and in the future. From this point of view the relative portion of SDS in the area will be an important element in the evaluation. Apart from any nature management objective, a normal functioning habitat with specific characteristics can develop on polluted SDS. As for many organisms an adaptation mechanism or an avoidance behaviour for pollution is found, besides the processes in soil leading to ageing of pollution, it can be expected to keep on functioning over a long period. Translated to spatial planning, the whole area is selected as nature area in the first stringent case, while in the second case, polluted sites have an adapted risk-reducing function within a larger area.

In contrast to nature management starting from the SDS as a soil substrate, environmental management focuses on the SDS as a polluted waste material. The geographical impact of SDS can be locally high. Dredged sediments are clearly classified as waste products by European and regional legislation. The save and coherent disposal of this waste material is a current topic for the Flemish government. We define the volume-to-area ratio (V:A) as an important measure representing the surface use efficiency for evaluation purposes. On a site where sediments are landfilled up to 2 meter the available space is used more efficiently, which is shown by a higher V:A. In general 2 groups of SDS can be distinguished: (1) recent landfills, with special protective measures, sometimes constructed in former sandpits or above dumpsites and with larger surfaces and higher V:A and (2) the older landfills and OSZ, which are scattered over the alluvial plain and have very low V:A. For the recent landfills, clearly stated legislative limitations for reuse of the site are delineated and ‘save’ land-uses (especially after capping) are planned. For the older landfills and OSZ, no land-use limitations exist, as these sites are not identified as being a landfill and/or being polluted. Before selecting a target nature development goal, nature management objectives must be confronted with environmental management objectives and the feasibility of combining both objectives must be evaluated.

Study area

In the study area a nature rehabilitation project was initiated to restore the alluvial wetlands as a breeding ground for meadow birds by aiming at retardation of the drainage in spring, especially for the “Reymere” part (Fig. 1) (VLM, 2001). However, soil pollution due to overbank sedimentation is one of the major constraints, which was initially underestimated due to its low visibility. Its impact on the area is large, both by a lower habitat quality and the risks of pollution.

The current situation in the study area is a consequence of a complex series of processes and human activities, and these processes resulted in a stressed habitat. We want to determine how this stressed situation reduces the feasibility of the nature rehabilitation project. The Cd concentrations in the topsoil are higher than the maximum permissible levels for normal soil functioning (Crommentuijn et al., 2000). Several basic soil functions (Nortcliff (2002): (a) create a physical, chemical and biological environment for living organisms, (b) allow biological activity and diversity for plants and animals, (c) regulate soil hydrology, nutrient balance and cycling and (d) filter, buffer, immobilise en decompose compounds) might be limited in this stressed circumstances. It must be clear that the substrate of sediment-derived soils is completely different from normal alluvial soils. As a consequence, spontaneous habitat development can be expected to be quite different than for unaffected alluvial soils. Especially the very eutrophic soil conditions are restricting the development of rare/endangered plant species as more common or generalistic species are favoured in these circumstances.

III. Risk evaluation

Both actual and potential risks must be considered. Actual risks are mainly linked with species diversity and abundance and risks of secondary poisoning and dispersal of pollutants. Potential risks are dominated by soil acidification, resulting in a tremendous increase of heavy metal bioavailability (Ma & van der Voet, 1993) and leaching risks (Singh et al., 2000). Potential risks are a function of the SDS configuration (sediment layer thickness, flooding frequency, hydrology and topography) and land-use.

Actual risks are encountered on different levels: (1) plant and soil organisms populations can suffer from chronic toxicity or altered stress levels due to pollution or high nutrient levels and this results in a shift of species and abundances (exposure assessment). Especially the rare or endangered species being most vulnerable are involved here; (2) the presence of SDS result in habitat fragmentation, (3) soil processes and functions such as litter decomposition can be hampered (effects assessment) and (4) there is a risk of secondary poisoning for higher levels of the trophic chains (risk characterisation).

Soils polluted with heavy metals can result in a reduced food abundance for higher trophic levels (reduced food quantity) and in higher body concentrations for soil invertebrates serving as feed for higher organisms (reduced food quality) (Klok et al., 2000). Higher heavy metal concentrations in calcareous SDS resulted in higher body concentrations for earthworms and isopods (Beyer & Stafford, 1993, Hendriks et al., 1995). An indirect effect of soil pollution is a possible food shortage for higher levels in the food chain (Hörnfeldt & Nyholm, 1996) or a changed, less optimal diet (Groen et al., 2000). Secondary poisoning is highly dependent on configuration of the polluted area and ecology of the target species (Menzie et al., 1992).

Potential risks are mainly dominated by the rate of soil acidification. In calcareous soils, both acid rain and root activity can result in soil acidification. In upland soils, the decalcification rates are 0.015-0.04% $CaCO_3$/year (Van Breemen & Protz, 1988), but in periodically waterlogged soils decalcification rates increase with one order of magnitude to 0.1-0.3%/year (van der Sluis, 1970; van den Berg & Loch, 2000). In permanent waterlogged situations, decalcification rates might be comparable with upland situations. Input of $CaCO_3$ in the topsoil is possible as a result of floodings and circulation of elements due to litter fall.

Study area

Actual risks are an altered food abundance and quality for meadow birds, potential risks are dependent on rates of soil acidification. Both bioavailability and effects of pollutants must be considered for determination of actual risks. Actual risks in the study area were studied by determining bioavailability of heavy metals for plants and insects and effects of soil pollution on earthworm communities.

For both willows and poplars, polluted sediment-derived soils resulted in elevated and deviant foliar concentrations. For poplars, higher Cd concentrations were measured in leaf beetles feeding on foliage with deviant Cd concentrations (Vandecasteele et al., 2002b, Vandecasteele et al., 2003). However, no toxic features for trees were observed and litter decomposition rates were evaluated as normal. Earthworm abundance and species diversity was studied in unaffected alluvial soils, polluted overbank sedimentation zones and DSDS. Results indicated slow colonisation of DSDS by endogeic and anecic species, while epigeic earthworm species were abundant, even for recent DSDS flooded during winter and spring. Highest earthworm biomass was found for the unaffected alluvial soils while lowest earthworm biomass was observed on polluted DSDS. Results indicate clear effects of soil history and pollution status on earthworm abundance and species diversity on one hand and the complexity of risk estimation of secondary poisoning on the other. Lower earthworm biomass on DSDS results in a lower risks for predators.

Soil decalcification and thus potential acidification is largest in parts with alternating oxidised and reduced soil conditions (Dirksz et al., 1990; van den Berg & Loch, 2000), which is most probably the case for the alluvial soils used for clay reclamation. In the study area, the $CaCO_3$ content in the A-horizon was on the average 1.5 % lower compared with the C-horizon ($p = 0.000$) for all soil profiles (unaffected alluvial soils, excavated soils both with or without influence from overbank sedimentation). The $CaCO_3$ content was highest ($p < 0.01$) in the topsoil for soils polluted by overbank sedimentation (4.2%) in contrast to the unaffected topsoils (2.9%). These values are however lower than the 4.3-11.9

% range observed in DSDS in the area (Vandecasteele et al., 2002a). In 38 of 52 soil samples of the excavated area subjected to overbank sedimentation, $CaCO_3$ contents are higher than 2%. Future soil monitoring must focus on $CaCO_3$, pH and organic matter balance.

IV. Risk reduction

An overview of risk-reducing management objectives is now given, with indication of the feasibility and the uncertainty. Drastic and expensive options are capping and excavation, both resulting in a clean habitat without actual or potential risks. The less drastic options are hydrological management and lime, gypsum or nutrient amendments and focus mainly on the reducing of potential risks of soil acidification.

IV.1. Oxidation/reduction = hydrological management

Reduction of the substrate of SDS results in immobilisation of heavy metals due to binding as sulfides and thus a lower leaching potential and a reduced bioavailability (Gambrell, 1994). Sulfide binding is a function of redox potential. However, also carbonate budget must be considered. In a permanent flooded situation, carbonate dissolution rates are comparable ore lower than in upland situations, but the intermediate situation is less optimal as in periodically waterlogged soils carbonate dissolution rates are generally ten times higher. Influx of carbonates through floodings or litter must also be considered in the carbonate budget. The hydrological management affects also the soil binding capacity and the availability of phosphates, especially for drained wetlands (Baldwin et al., 2000; Venterinck et al., 2002).

IV.2. Liming and phosphogypsum amendments

Amendments of lime and gypsum can reduce soil decalcification and bioavailability of heavy metals. Carbonell et al. (1999) concluded that phosphogypsum amendment to Missisipi River alluvial sediments reduced aqueous concentrations of toxic heavy metals to trace levels under anoxic conditions by precipitating these toxic elements as insoluble sulfides. Pierzzynski & Schwab (1993) compared the effect of various soil amendments or combinations of amendments on Zn, Cd and Pb bioavailability in a metal-contaminated alluvial soil and conclude that the limestone amendment was the most effective treatment.

IV.3. Excavation and relocation of the sediment substrate

Excavation is a drastic operation resulting in a uncontaminated habitat for plants and soil organisms. Excavation an relocation of older DSDS was applied successfully along the Ghent-Bruges Canal because of nature rehabilitation purposes (Decleer, 1994). In the Netherlands, floodplains were partly lowered by excavation for water management and river rehabilitation objectives (Faber et al., 2001). Feasibility is very dependent on the sediment layer thickness of the SDS. We propose that maximum layer thickness acceptable for excavation is 75 cm. For thicker layers, capping is a more feasible management objective.

IV.4. Capping

Dredged sediments have suited properties to function as a barrier layer and are therefore used as capping layer above other landfills (van Driel & Nijssen, 1988; Mohan et al., 1997; Tresselt et al., 1998). Capping layers above SDS are thus only necessary to provide a clean habitat for plants and soil organisms. For effective risk reduction for soil biota, a capping layer of 40-50 cm must be sufficient (Bosveld et al., 2000). For all plants without higher heavy metal uptake on SDS or with a shallow root system, a covering layer of this thickness is sufficient to prevent interaction with the deeper sediment layer. For willows and poplars, a thicker covering layer is necessary, and only a liner can probably prevent root penetration into the sediment layer and the resulting higher foliar concentrations (Vandecasteele et al., 2002b; Vandecasteele et al., 2003). When capping is used, it is better to avoid willows ands poplars to grow. We propose to use capping layers with similar grain size distributions as the sediment layer. The application of this covering layer resulting in a levelling up of the site must be evaluated against landscape and habitat criteria. Therefore we think that it must be unreasonable to cap sites with a sediment layer < 60 cm with a covering layer of 40-50 cm.

IV.5. Manuring and tillage

Both manuring (Lorenz et al., 1994) and tillage of polluted SDS result in a decreased pH and a higher bioavailability of heavy metals. Agricultural use of polluted SDS must thus be avoided, all the more soil pollution status was found to result in exceeding the permissible levels of heavy metals in feedstuffs public health standards. In contrast, ameliorating the soil nutrient status can reduce toxic effects of pollutants in oligotrophic situations.

Study area

The most drastic option for the Reymere, the central part of the study area, is the excavation of the sediment layer, resulting in the removal of all actual and potential risks and the restoration of the natural habitat. Future overbank sedimentation of polluted sediments must however be avoided. As long as floodings result in supply of polluted sediments in the area, excavation is useless. Capping is not a realistic option as sediment layer thickness (20-30 cm) is low. A more pragmatic alternative focuses on the reduction of soil acidification rates and a monitoring of the effects of soil pollution on soil organisms.

Most nature rehabilitation projects in alluvial areas focus on wetland restoration. Wetland restoration of polluted sediment-derived soils can result in a reduced soil topsoil and thus a lower bioavailability of heavy metals. Therefore, the soil profile should be waterlogged year in year out. For each case the feasibility of permanent waterlogging must be determined and the expected vegetation in the waterlogged case must be confronted with the proposed target vegetation.

V. Conclusion

Sediment-derived soils developed spontaneously as a consequence of overbank sedimentation or are human-made as disposal site for dredged sediments, and were characterised by heavy metal pollution. Soil properties of sediment-derived soils clearly deviate from normal unaffected soils due to the pollution status and the high nutrient concentrations. Besides the low probability of acute or chronic toxicity for plants and soil organisms in direct contact with the polluted substrate, a large uncertainty is involved with the risk assessment for secondary poisoning. There is a clear need for a frame of reference for nature management in polluted areas.

For nature areas affected by SDS, realistic and straightforward criteria for nature and environmental management objectives are needed. Currently, a contradiction is found in legislation with stringent criteria for construction of new dredged sediment landfills while overbank sedimentation of polluted sediments in alluvial plains and constructed wetlands is considered to be a natural process without further constraints. Spatial and management planning for alluvial plains must start from the knowledge that pollution due to sediment dispersal might be present instead of ignoring environmental issues in nature management. It is obvious that SDS are strongly deviant from the normal alluvial soils and thus cannot match the processes and habitat linked with alluvial soils. However, pragmatism leads to management of polluted SDS focusing on avoiding hinder for the functioning of the whole area. As there are many obstacles for expensive and drastic management options such as capping and excavation, our on-going research focuses on the determination of the dynamics of soil forming processes on sediment-derived soils and the long-term consequences of less drastic risk-reducing management options such as hydrological management.

References

Baldwin, D.S., Mitchell, A.M., Rees, G.N. 2000. The effects of *in situ* drying on sediment-phosphate interactions in sediments from an old wetland. Hydrobiologia 431, 3-12.

Beyer, W.N., Stafford, C., 1993. Survey and evaluation of contaminants in earthworms and in soils derived from dredged material at confined disposal facilities in the great lakes region. Environmental monitoring and assessment 24 (2), 151-165.

Bosveld, A.T.C., Klok, T.C., Bodt, J.M., Tutgers, M. 2000. Ecologische risico's van bodemverontreinigingen in toemaakdek in de gemeente De Ronde Venen. Alterra-rapport 151, Alterra en RIVM, Wageningen en Bilthoven.

Carbonell, A.A., Porthouse, J.D., Mulbah, C.K., DeLaune, R.D., Patrick, W.H. Jr., 1999. Metal Solubility in Phosphogypsum-Amended sediment under Controlled pH and Redox Conditions. J. Environ. Qual. 28, 232-242.

Crommentuijn, T., Sijm, D., de Bruijn, J., van den Hoop, M., van Leeuwen, K., van de Plasssche, E. 2000. Maximum permissible and negligible concentrations for metals and metalloids in the Netherlands, taking into account background concentrations. Journal of Environmental Management 60, 121-143.

Decleer, K. 1994. Herstel laagveenmoeras in de Leiemeersen (West-Vlaanderen*).* De Levende Natuur, 95(6), 218-219.

Dirksz, P.W., Lotte, M.L., Palsma, A.J. 1990. Ruimtelijke verspreiding van zware metalen en arseen in de Biesbosch. Eindrapport. Rapport aan RWS-DBW/Riza en RWS-Directie Zuid-Holland.

Faber, J.H., Burgers, J., Aukema, B., Bodt, J.M., van Kats, R.J.M., Lammertsma, D.R., Noordam, A.P. 2001. Ongewervelde fauna van ontkleide uiterwaarden. Monitoringsverslag 2000. Alterra-rapport 287, ISSN 1566-7197, Alterra, Wageningen, 58 p.

Gambrell RP. 1994. Trace and toxic metals in wetlands - a review. Journal of Environmental Quality, 23, 883-891.

Groen, N., Boudewijn, T., de Jonge, J., 2000. De effecten van overstroming van de uiterwaarden op de Steenuil. De Levende Natuur, 101, 143-148.

Hendriks, A.J., Ma, W.C., Brouns, J.J., de Ruiter-Dijkman, E.M., Gast, R. 1995. Modelling and monitoring organochlorine and heavy metal accumulation in soils, earthworms and shrews in Rhine-Delta floodplains. Environmental Contamination and Toxicology 29, 115-127.

Hörnfeldt, B., Nyholm, E.I. 1996. Breeding performance of Telmalm's owl in a heavy metal pollution gradient. Journal of Applied Ecology 33, 377-386.

Klok, C., de Roos, A.M., Broekhuizen, S., van Apeldoorn, R.C. 2000. Effects of heavy metals on the badger Meles meles: interaction between habitat quality and fragmentation. In: J.E. Kamminga & R. Laskowski (Eds), Demography in Ecotoxicology. Wilex, Sussex.

Lorenz, S.E., Hamon, R.E., McGrath S.P., Holm, P.E. & Christensen, T.H. 1994. Applications of fertilizer cations affect cadmium and zinc concentrations in soil solutions and uptake by plants. European Journal of Soil science, 45, 159-165.

Ma, W.C., van der Voet, H. 1993. A risk-assessment model for toxic exposure of small mammalian carnivores to cadmium in contaminated natural environments. The Science of the Total Environment, Supplement 1993.

Menzie, C.A., Burmaster, D.E., Freshman, J.S., Callahan C.A. 1992. Assessment of methods for estimating ecological risk in the terrestrial component: a case study at the Baird & McGuire superfund site in Holbrook, Massachusetts. Environmental Toxicology and Chemistry 11, 245-260.

Mohan, R.K., Herbich, J.B., Hossner, L.R., Williams, F.S. 1997. Reclamation of solid waste landfills by capping with dredged material. Journal of Hazardous Materials 53, 141-164.

Nortcliff, S. 2002. Standardisation of soil quality attributes. Agriculture, Ecosystems and Environment 88, 161-168.

Pierzynski, G.M., Schwab, A.P., 1993. Bioavailability of Zinc, Cadmium and Lead in metal-contaminated alluvial soils. J. Environ. Qual. 22, 247-254.

Singh, S.P., Ma, L.Q., Tack, F.M.G., Verloo, M.G. 2000. Trace metal leachability of land-disposed dredged sediments. J. Environ. Qual. 29, 1124-1132.

Sluis, P. van der., 1970. Decalcification of marine clay soils connected with decalcification during silting. Geoderma 4, 209-227.

Tresselt, K., Miehlich, G., Groengroeft, A., Melchior, S., Berger, K., Harms, C., 1998. Harbour sludge as barrier material in landfill cover systems. Wat. Sci. Techn. 37 (6-7), 307-313.

Van Breemen, N., Protz, R. 1988. Rates of calcium carbonate removal from soils. Can. J. Soil Sci. 68, 449-454.

Vandecasteele, B., De Vos, B. and Tack, F.M.G. 2002a. Heavy metal contents in surface soils along the Upper Scheldt river (Belgium) affected by historical upland disposal of dredged materials. *Sci. Total Environ. 290 (1-3)*, 1-14.

Vandecasteele, B., De Vos, B. and Tack, F.M.G. 2002b. Cadmium and Zinc uptake by volunteer willow species and elder rooting in polluted dredged sediment disposal sites. *Sci. Total Environ*. 299, 191-205.

Vandecasteele, B., Lauriks, R., De Vos, B. and Tack, F.M.G. 2003. Cd and Zn concentration in hybrid poplar foliage and leaf beetles grown on polluted sediment-derived soils. Environmental monitoring and assessment, in press.

van den Berg, G.A., Loch, J.P.G., 2000. Decalcification of soils subject to periodic waterlogging. European Journal of Soil Science, 51, 27-33.

van Driel, W., Nijssen, J.P.J., 1988. Development of Dredged Material Disposal Sites: Implications for Soil, Flora and Food Quality. In: Salomons W, Förstner U (Eds.) Chemistry and biology of solid waste. Dredged material and mine tailings. Berlin: Springer-Verlag.

van Straalen, N.M., Denneman, C.A.J. 1989. Ecotoxicological Evaluation of Soil Quality Criteria. Ecotoxicology and environmental safety, 18, 241-251.

van Strydonck, M., de Mulder, G. 2000. De Schelde Verhaal van een rivier. Davidsfonds, Leuven.

Venterink, H.O., Davidsson, T.E., Kiehl, K., Leonardson, L. 2002. Impact of drying and re-wetting on N, P and K dynamics in a wetland soil. Plant and Soil 243, 119-130.

VLM, 2001. Natuurinrichting project Merelbeekse Scheldemeersen. Projectrapport.VLM en AMINAL afd. Natuur, Gent. 122p. + kaarten.

Worm, B., Bos, S., Bakker, L., Spek, M., 1998. Natuurontwikkeling op verontreinigde locaties, een beslissingsmodel en de eerste ervaringen. Landschap 15/4, 195-210.

RESCUE – SUSTAINABLE REGENERATION OF EUROPEAN SITES IN CITIES AND URBAN ENVIRONMENTS

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The scope of RESCUE

The process of industrial change has resulted in the creation of so-called „brownfields“ across Europe - particularly in urban and industrialised areas. Brownfields present the heritage of the prosperous phase of industrial activities. They are in many cases an integral part of a city's structure instantly affecting the quality of urban life. Although there is not yet a precise and legally binding definition about brownfields there is a common understanding about the problems that brownfield sites can present or create. Brownfield sites are derelict or underused, have in many cases real or perceived contamination problems, present adverse effects to the quality of urban life and need intervention from outside to be brought back to beneficial use respectively be reintegrated into the economic cycle. Today, the management of the increasing amount of derelict land in inner city locations is one of the most important issues. Such sites present particular challenges to national and regional policymakers. The reintegration of brownfield sites into the urban and economic structures of cities is one of the essential objectives of sustainable urban planning.

Developing brownfield land is a complex issue. It means dealing with the different interests of a variety of stakeholders, including regulators, investors, land owners, developers, consultants, academics, community groups, technology providers and the financial sector. It also means dealing with contamination. However, there are many much wider aspects that need to be considered and integrated into action to achieve effective solutions. The political, social and economic context of brownfields becomes clearer through analysis of related aspects in these areas:

- Breakdown of economics,
- Problems in attracting new investors,
- High unemployment rate,
- Adverse effects on urban life,
- Decline of tax income for the communities,
- Social conflicts,
- Consumption of greenfields

Within the area of work of the European Commission brownfields have been on the agenda of infrastructure and economic development aid for many years. A link to specific issues of environment, contamination and research has been first established by the EC project CLARINET. This research network on contaminated land established a specific working group on brownfields. Programmatic implementation of this issue took place as part of the EC 5th Framework Research Programme 1998-2002. The redevelopment of brownfields was explicitly identified as priority research area within the Environment and Sustainable Development Programme (thematic priority EESD-1999-4.3.1 in the new key-action “The City of Tomorrow and Cultural Heritage”).

Project description
RESCUE stands for *Regeneration of European Sites and Cities in Urban Environments*. It is funded within the Fifth Framework Research programme of the European Commission. The consortium is made up by 14 partners from France, Germany, Poland and the United Kingdom representing a wide range of stakeholders within the redevelopment process (details are available at www.rescue-europe.com). The coordination of the project is with the German company GPE (Gesellschaft für Projektmanagement und Grundstücksentwicklung mbH). The project was launched in March 2002 and will terminate in March 2005.

Objectives
RESCUE is aiming at the development of best practice for brownfield redevelopment. The primary mission is to develop and test a holistic system approach for the sustainable regeneration of urban brownfields in Europe. This means in essence that RESCUE will try to establish a link and guidance on how to redevelop brownfields in a real sustainable way. The underlying principle for all research activities is the framework of sustainable development. The project is designed to provide some practical links to the real issue of brownfield redevelopment based on the original definition for sustainability of the World Commission on Environment and Development (Brundtland Commission) of 1987. This definition points out that *"Sustainable Development is a form of development which meets the needs of the generation of today without jeopardising the chance for future generations to meet their own needs."* The basic idea was it to link the needs of today's generations with the life prospects of future generations which finally means to create a balance between the needs of economic needs, environmental needs and social needs (dimensions of sustainability).

One of the essential output of the project will therefore be specific objectives and indicators to control and measure the process in a real sustainable dimension. Such objectives and indicators provide then the background tools for best practices that can be used by the variety of stakeholders involved in the process. Facing the complex economic, social and environmental nature of brownfields they are developed for the following three principal purposes:
1. To drive down the cost for:
   - bringing land back into beneficial use by industry and the community;
   - environmental remediation and recovery
2. To enhance regional economic development through the:
   - creation of jobs;
   - creation of cultural identity by means of citizen participation;
   - creation of tax incentives and revenue streams;
   - optimisation of infrastructure.
3. To enhance ecological regeneration by:
   - reducing the consumption of natural resources;
   - site preparation for construction purposes (demolition of buildings, soil remediation);
   - recovery and re-use of demolition and construction materials;
   - environmental upgrading and ecological improvement of former industrial sites through brownfield redevelopment and environmentally adequate spatial planning.

In detail, the results of this project will provide specific tools that will help to enable sustainable brownfield regeneration for regulators, planners, engineers and other stakeholders. They will encompass quality criteria for sustainable brownfield regeneration, tools for the management of contamination on brownfield sites, tools to promote the re-use of soil and construction related waste like tax incentives, funding or other fiscal measures, guidance on sustainable management options for existing buildings and infrastructures, guidance on sustainable land use and urban design on brownfield sites, etc. The final objective is the integration of all tools into a holistic system approach for Europe.

Structure and procedure of the project

The methodological approach is based on the investigation of brownfield redevelopment processes in the four participating countries, namely Germany, Poland, France and the United Kingdom. The idea is to analyse best practice in these countries, put them into relation to the framework and the principles of sustainability and identify specific issues that offer potential for modification for being more sustainable. The selection of the case study sites (two per country) therefore has been based on specific sustainability related criteria.
However, it was decided at the beginning of RESCUE that the projects must be located in industrial core regions of the countries. These core regions must have been significantly affected by economic decline in the context of the structural change. They are referred to in the section below.

In order to structure the research work most efficiently the regeneration process was broken down into the main steps of decision making. They are displayed in figure 1. The workpackages are all composed along the heading of achieving maximum synergies by mixing stakeholders and countries.

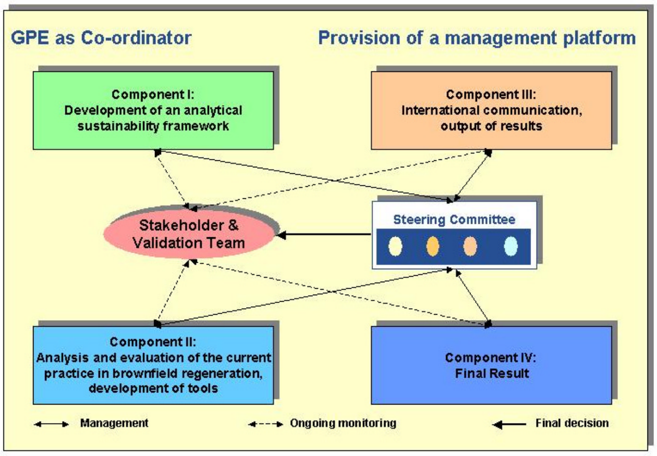


Figure 1: RESCUE components

As it is one of the essential objectives of RESCUE to identify brownfield specific sustainability indicators the development of an analytical sustainability framework is an indispensable precondition before analysing the projects. This is the main task of component 1. Component 1 provides the fundamental framework for the further conduction of the project. It is composed by a workpackage on environmental, economic, social and institutional criteria for brownfield redevelopment and the political, legal, social and economic framework of each participating country / region. This analytical framework is necessary background for the subsequent comparison of the projects. Such comparison has to consider that the projects are taking place in different countries with a different political and economic/industrial history in different legal and planning systems and under different economic and social conditions. Workpackage 1 has also provided specific criteria for the selection of appropriate project in the scope of RESCUE (see below).

The specific analysis and evaluation of current practice in brownfield regeneration is essentially part of component 2. It will be done by investigation and analysis of ongoing projects. These projects have been nominated and selected according to specific criteria. In all, there are 5 workpackages working along the development of tools for the regeneration of brownfields. The research undertaken is structured along engineering workpackages (management of contamination and the handling of buildings and infrastructures), planning workpackages (Sustainable land use / urban design and Sustainable planning processes), and purely to the process, to co-ordination and to management related workpackages (methods for citizen participation, management and integrated methodological approaches).
Component 3 of the project is the major element to ensure sufficient communication of the intermediate results and deliverables to others. This component will bridge the gap to countries and stakeholders who are not actively involved in the RESCUE work. Component 3 is intended to serve as a kind of quality assurance and as a teaching tool that will bring comments and reviews from other parties, especially end users of the RESCUE manual, into the research work. Basically, there are three elements performed within specific work packages to achieve these goals:

1. Development of a virtual training centre which
   - is designed as a web based training package that will enable anyone to understand the main conclusions and lessons to emerge from the project
   - provides web based training resources for self teaching and for use in face-to-face training, such as stand alone readers - text explaining specific topics, illustrated 'powerpoint' type presentations, video and audio clips to illustrate specific points from the case studies, self teaching aids - such as quizzes, questions, and problems, etc.

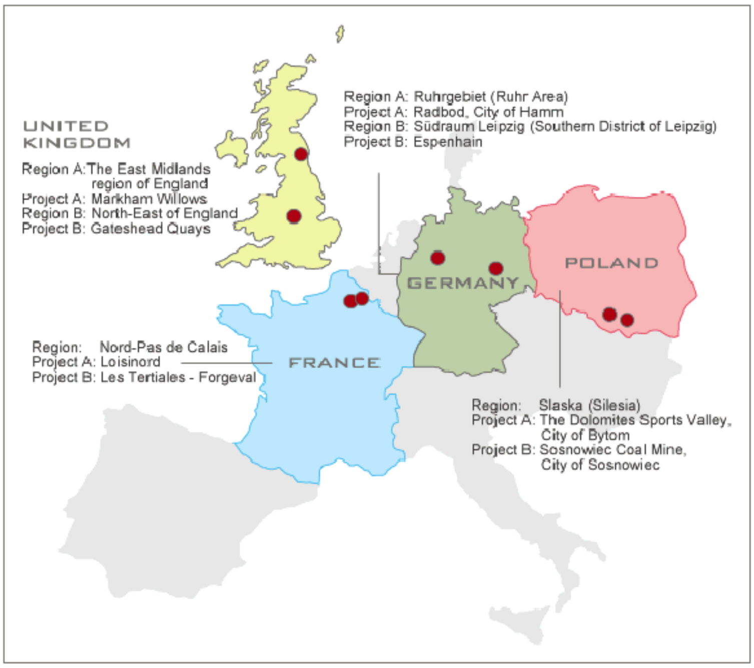
2. Establishment of a stakeholder and validation team
   - to bridge the gap between RESCUE and countries and stakeholders who are not involved
   - to identify potential weaknesses from an end users viewpoint
   - to review and validate the deliverables
   - to perform practical trials of decision support tools for specific stakeholder groups as well as feasibility checks on options/restrictions concerning the implementation of developed tools into national frameworks
3. Structured dissemination of the findings of the project as regards among others
   - liaison to other relevant networks
   - organisation of project workshops
   - writing regular newsletters and responding to call for papers
   - inspiring the project partners for publications

Component 4 will integrate the individual results and deliverables into a System Approach for Europe. It will be published as a Manual for Sustainable Brownfield Regeneration.

The manual is subject of dissemination throughout Europe to potential end users and scientific networks. Key guidance of the manual will be translated into the Polish, German, French and Russian languages for wider access.

Case Study Sites and Regions

In order to picture the full social, economic and environmental scale of brownfields it was decided that the pilot projects have to be located in such regions of the partner countries which are significantly affected by the structural industrial change in its full economic, social and environmental dimension. Such core regions are Nord-Pas de Calais (France), North East of England and East Midlands (United Kingdom), Silesia (Poland) and the Ruhr Region plus the region South of Leipzig in Germany. To ensure that the sites will meet the requirements of RESCUE and provide enough and appropriate information concerning the elements of sustainability a set of general and specific criteria for the sites has been elaborated.



Generally, it was important that

- the redevelopment process was as much advanced as possible,
- the sites represent the interests of all workpackages,
- lessons in terms of approaches focusing on sustainability and participation for the current practice in brownfield development are available,
- the selected sites were comparable (e.g. in terms of the previous land use (heavy industries), size (large industrial sites), etc.,
- data were available,
- significant social influence is present.

Specifically, in the process of site selection RESCUE had also a closer look at criteria like sustainability, soil and debris, buildings and infrastructure, urban context, participation, integration of social and engineering sciences, starting year / year of intended finalisation, previous land use and intended after land use.

The profiles of the sites and the regions in the countries are described below.

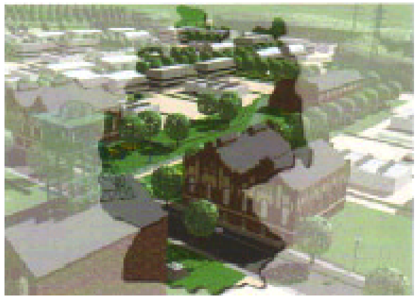
Nord-Pas de Calais - FRANCE
The Nord-Pas de Calais Coalfield is the largest in France (206 372 hectars):100 kilometres long and only 15 to 5 kilometres wide.
The coalmining industry started in 1720 : 1960 is the symbolic starting point of the planified decline of coal production in the Nord/Pas de Calais. Two famous National Programs - "Plan Jeanneney 1960 - 1965" and "Plan Bettencourt 1968" - drastically reduced coal production and led to the closing of the least competitive sites. Despite desperate attempts to strenghten coal production in the early eighties, the coal decline was inexorable in the Nord-Pas de Calais, and in Europe. It stopped in December 1990 in Oignies.

The key figures of this region are: :

- 1.200 000 inhabitants out of 4 millions for the whole region
- 180 local authorities ; 2 Departements
- more than 220 000 people were directly employed by the coalmining industry at its climax
- galleries : 100 000 km
- brownfields : 5 000 hectars
- 232 tips
- 80 379 coalmining housing estate
- strong subsidence : 10 to 18 metres
- water problems : 60 electric pumps (annual cost : 1 524 000 EUROS)

Two projects in this region will be analysed (Loisinord and Les Tertiales)

Ruhr area and Südraum Leipzig - GERMANY
Germany has chosen one region in the western part of the country (Ruhrgebiet) and one region in the eastern part of the country (Südraum Leipzig).



The term Southern District of Leipzig (Südraum Leipzig) stands for a geographical, residential and economic area straddling the federal states of Saxony, Saxony-Anhalt and Thuringia. Stretching between Leipzig, Zeitz and Altenburg, it consists of 450 sq km in Saxony, with a population of some 110.000 out-side the city of Leipzig. Südraum Leipzig is defined primarily by its industrial economic and social history. The details of the chosen site Espenhain is given with table 1.
The Ruhrgebiet is one of the oldest and largest industrial regions in the world with nearly 5.3 million inhabitants living on 4.443 sq. km (1.193/sq km: five times as densely populated as the average in former West-Germany) in 11 cities and another 42 towns and cities belonging to 4 counties (Kreise). The data profile of the choosen site Radbod is given with table 2.

Location	Central location in the former lignite basin "Südraum Leipzig" between the city of Leipzig and Borna
Site: size / previous use / urban context	• Former chemical plant, briquette factory and 2 power stations
Contamination and Debris	• Organic pollutants, metals • Waste tip from lignite mining
Buildings and Infrastructure	• Demolition works since 1990, remaining industrial monument, power station, and administrative buildings
Concept/Future Use	• Industrial- and Science park, cultural uses in the former briquette factory
Realisation	• Ongoing, Industrial park 2002 - 2004

Table 1: Espenhein (Südraum Leipzig)

Location	Hamm-Bockum-Hövel, in the north-east of the Ruhr Area
Site: size / previous use / urban context	**Location in the city and surrounding land uses** • directly south of the urban area of Hamm-Bockum-Hövel • green spaces to the west, south and east **Traffic access / connection:** • motorway A 1 (to Bremen / Cologne), aprox. 8 km • motorway A 2 (to Berlin / Oberhausen), aprox. 11 km • high speed train stops at the railway station of Hamm **Size**: 21 ha **Previous use:** • coal mine named Radbod 1/2/5, including the cookery Radbod • started 1904 • extraction since 1906 • 1976 closure of the cookery • 1990 closure of the coal mine
Contamination and Debris	• 1992 to 1995 exploration/ investigation phase with an historical inquiry • 1997 to 1998 development of the sanitation and preparation concept • 1999 start of preparation and coverage of the project area • Remediation / soil management • necessity to partly fill up the area, because of mining subsidence • soil with light concentrations of hydrocarbon and others were safely accumulated in the southern part of the project area • removal of constructional barriers/ obstacles, also in the underground • disposal of heavy contaminated materials
Buildings and Infrastructure	**Buildings**: • the old porter-house • the vehicle hall • shaft towers (2x): listed buildings • steam engine house: listed building • shaft Winkhaus (shaft n° 5), this one is still in operation
Concept/Future Use	• Industry • The concept bases on a divers and flexible design. Important facts are the integration of historical buildings, existing greens, the divers design of streets, including green and different squares. The concept should be flexible to react on and integrate the ideas and desires of the investors. The so called "module plan" with its special raster offers a very flexible partitioning of the lots. The objective is to create a harmonically urban overall picture. • Legally binding land use and building plan ("Bebauungsplan") has been elaborated
Realisation	• 1995 - 2002 • Three plots of land have already been sold

Table 2: Radbod Site

The East Midlands and the North East of England – UNITED KINGDOM

Also in the United Kingdom, two sites in two specific regions are subject of investigation. The East Midlands is the fourth largest region in England – it has a population of 4.1 million. The main centres of population are the cities of Derby, Leicester and Nottingham; although more than a third of the region's residents, almost twice the national average, live in rural areas. The East Midlands has a striking economic, social and environmental diversity. Especially the Northern Coalfields Sub-Region is a priority for regeneration due to having been severely affected by industrial decline, particularly in coal mining, which has lost some 55,000 jobs since 1981, and also textiles and engineering. The effects of colliery closures include environmental degradation, poor employment prospects, and an emigration of skilled workers. The profile of the Markham Willows site is displayed in table 3.

The North East of England is one of the smallest of the English regions in both area (8,592 sq.m) and population (2.6 million). It is a region of contrast, over half of which is rural incorporating two National Parks. The region has experienced enormous changes over the past 50 years. Between 1981 and 1997, the North East lost over 110,000 jobs in primary and manufacturing industries, representing 10% of the workforce. A survey undertaken in 1997 identified 448 hectares of derelict land within Gateshead. Although a significant amount of land within Gateshead has been reclaimed, more is being identified due to the closure of industrial sites and the need for further reclamation of existing sites. The amount of land contaminated within Gateshead is likely to be extensive due to the effects of industrial use. The sites profile is given with table 4.

Location	Bolsover, Derbyshire, East Midlands Region of England
Site: size / previous use / urban context	• Coal mine • Tip • 200 ha
Contamination and Debris	• Dioxins • Metals
Buildings and Infrastructure	• Most of the structures were demolished in 1990s. This was normal practice at the time
Concept/Future Use	• Commercial use of the colliery site; the tip will be used to produce biomass (willow trees) to provide heat and energy for the new uses on the colliery site; • Project design includes job creation, training, education, waste management, renewable energy, risk management, public amenity, wildlife habitat
Realisation	• 2002 - 2004

Table3: Markham Willows site

Location	Gateshead, Tyne and Wear, North East Region of England
Site: size / previous use / urban context	• Harbour • 2,000,000 m
Contamination and Debris	• Oil • Metals
Buildings and Infrastructure	• Major structures retained, e.g. the Baltic Mill
Concept/Future Use	• Social, cultural and economic regeneration
Realisation	• 1999 - 2005

Table 4: Gateshead site

Silesia - POLAND

Silesia region (voivodship) is situated in south part of Poland and consists of 19 cities 17 districts and 166 communities. It covers an area of 12 294 square kilometers and accommodates 4 882 400 people. The density of population in this region is equal to 397 person/ square kilometers which 3,2 times higher than average. Silesia is considered as the environmentally most degraded area in Poland. Since the 19th century the Upper Silesia Coal Basin of Poland has been one of the world's most famous mining centres (producing 130 million tones of hard coal per year), and also a centre for the study of environmental changes in mining-influenced areas. An area of almost 600 km^2 is affected by damage caused by underground exploration. Two sites have been chosen from this area. Their profiles are given with tables 5 and 6.

Location	Sosnowiec, Silesia
Site: size / previous use / urban context	• Coal mine • 31 ha
Contamination and Debris	• Spoil bank (high max 8,0 m over the adjacent area) • Coal mining wastes
Buildings and Infrastructure	• Office building (3-floor administration and social building) • Two workshops and storage facilities • New manufacturing plant • Pit shaft hoist tower
Concept/Future Use	• Industry • Services • Housing
Realisation	• Beginning in the year 2001

Table 5: Sosnowic Coal mine

Location	Bytom, Silesia
Site: size / previous use / urban context	• Dolomite open cast mine • 38 ha
Contamination and Debris	• Low concentrations of heavy metals • No significant constraint for redevelopment
Buildings and Infrastructure	• Original buildings and infrastructures have been dismantled
Concept/Future Use	All year leisure and recreation centre including an artificial ski slope, equestrian centre, mountain biking tracks, climbing wall, minigolf
Realisation	• The recreation centre will be opened in December 2002

Table 6: Bytom site

Final Remarks

RESCUE combines for the first time the principles of sustainable development with a particular field of application. It is therefore an approach to demonstrate what sustainability can mean in the practical terms for the work of planners, engineers, regulators or NGO's. The expected impact of RESCUE is the acceleration of brownfield redevelopment by introducing new standards for the integrated approach for all stakeholders. The key element of RESCUE will be a Manual of a European System Approach for Sustainable Brownfield Regeneration. It will provide a holistic system approach that may be used throughout the European Community as well as in EU accession States. It will be a substantial decision making tool for stakeholders, public administration and financial funding bodies. It will provide checklists, performance indicators, evaluation criteria and examples of best practice that have been evaluated within RESCUE. Economic tools for the enhancement of brownfield regeneration will be proposed (e.g. tax incentives etc.). Furthermore, decision making tools for funding organisations on the national, regional or even European level will be part of the manual.

RESCUE is now in the phase of detailed analysis of the pilot projects. It progresses very well and is full in line of its schedule to achieve the goals that have been set. The progress of RESCUE can be observed via its web site at www.rescue-europe.com.

References

RESCUE homepage, http://www.rescue-europe.com

RAG Immobilien, Städte von heute, Städte von morgen, http://www.rag-immobilien.de/riag/2002/200210_staedte_von_heute-staedte_von_morgen.htm

D.2 Lecture Session:

Communication and Stakeholder Perspectives

RISK BASED OR BIASED CONTAMINATED LAND MANAGEMENT: CONCEPTUAL CLARIFICATIONS FOR MORE COMPREHENSIVE AND BALANCED VIEWS AND POLICIES

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1 INTRODUCTION

From cleanup of hazardous waste sites and contaminated soil sites, contaminated land management has emerged as a broader concept and approach emphasizing the extent of contamination, or indeed also of other risk agents, and of responses to them. In Europe this was reflected e.g. in concerted actions first on contaminated sites (CARACAS, see Ferguson et al. 1998) and then on contaminated land (CLARINET). A concurrent development has been an emphasis on "risk basis" of management, resulting e.g. in the Risk Based Land Management (RBLM) concept. The closely related concept Risk Based Corrective Action (RBCA) has been developed especially within oil industry, also as standard procedures e.g. by ASTM (see Khan and Husein 2001), and adopted in Europe e.g. by CONCAWE.

These developments are understandable and in many respects justified and sound, partly as reactions to the financial, institutional and implementation constraints and to the overall contexts of environmental cleanup programs both in USA (Kavanaugh 1996) and in Europe. These reactions have included adjustments in estimates of the magnitude and the focus of the problem or of the resources available to solve it, as e.g. with the shifts in Dutch soil protection policy from the original ambitious objectives of broad multi-functionality of soil to prioritization of urgency based e.g. on land use (Keuzenkamp et al. 1990; Denneman 1999). Also new problems or new aspects of old problems have surfaced. Importantly, redevelopment of 'brownfields' (old industrial and other such derelict areas) has become a more pressing task (e.g., Geltman 1996; McCarthy 2002). Such developments have partly been a natural consequence of having to revise priorities, as the scope of activity expanded from immediate hotspot remedies to other areas, e.g. land-use planning, industrial and urban modernization, overall soil and groundwater quality management, and other areas of (environmental) management and technology. Background risks have become important here (e.g., Smith et al. 1996). The rise of RBLM can also be seen as a quest and request, in many ways necessary and welcome, for better knowledge base, rationale and analytical tools of contaminated land management.

However, RBLM and particularly the more general strives that the concept conveys also have notable problematic aspects with regard to e.g. the underlying valuations and intentions, and to the associated modes of thinking, communication and action. The term has been borrowed and used ambiguously, rigidly and uncritically, even with hidden connotations to contrast such management with alleged ignorance or exaggeration of 'real' risks, e.g. in relation to guideline value based management. Advocates of RBCA have also presented it as superior to rigid and costly "political" management approaches (e.g. Kavanaugh 1996). 'Risk based' has thus been hailed (or feared) as a synonym for more (or less) 'reasonable' cleanups. Such uses of and reactions to the concept, easily leading to – and resulting from – biased views and policies, boil down to fundamental questions of what risks are considered, why and how. It is also illustrative to see RBLM in relation to other phenomena in environmental and chemicals policy, particularly comparative risk evaluation (see e.g. Finkel 1995 and 1996), and as an example of general psychological, socio-cultural and political factors and tendencies.

Meanwhile, it has been realized also in official policies that risks are multidimensional, and far more than mere numbers (e.g. Health Council of the Netherlands 1996). Risk based decision making and related perception, communication, valuation and policy issues have been studied increasingly in general analyses of subjective notions regarding risk and uncertainty (e.g., Slovic 1987 and 1999; Brun 1995) and in many application areas such as health, safety, environmental protection and resource use, also in property development focusing on economic risks (Byrne 1984; Clarke and Reed 1988; cf. the comparative evaluation of European policies by Hollis and Percy 1998). There is also a growing recent literature on planning, economic and other societal aspects of contaminated land management especially in the development of brownfields (De Sousa 2000; Greenberg and Lewis 2000; Meyer and Lyons 2002). More generally, awareness of risks as social constructs has grown, based in part on the exposition of 'risk society' by Beck (e.g. in Lash et al. 1996). In a post-9-11 world such awareness has become still more acute. Yet, partly because of this, a narrow and illusory view persists of risks as neatly quantifiable and controllable entities, and of policies having to be simplistically risk-based.

Conceptual analyses of the relevant natural and human phenomena as well as critical studies of the underlying motivations are a key to broader and more balanced and thus better justified and properly "risk based" management of contaminated land. In such analyses, more attention should be paid to relations between 'facts' in natural and technical spheres with social ones, and to scrutiny of assumptions and arguments and their determinants. Such views are needed as contaminated lands and their management are linked with questions of knowable states and justified goals and actions.

2 METHODOLOGICAL APPROACH

Here I pursue a philosophical, behavioral and socio-political analysis of RBLM. I emphasize critical inquiry into the meaning and thus also into the limits of these concepts and of their applications. The general methodology integrates systems analytical approaches with considerations of psychological, e.g. cognition related, and communication aspects.

In the conceptual analysis, I delineate contexts and contents of the entities constituting the objects and means of management, with particular reference to their interactions. As a corollary, I describe relations between the 'objective' world of management, and perceptions, valuations, communications, agreements and other internal or social representations of it. I stress the types, importance and uses of the related concepts risks, uncertainties, impacts and benefits; symbols of such expressions; actor relations in cognition of and response to risks, and relations between science and management.

I develop the general analysis by two cases: a) guideline value based contaminant management in relation to site-specific decision criteria; b) the uses and misuses of 'models' of risks. I here utilize data on cleanup activities and illustrative examples, largely contrasting tendencies. However, essentially this work is not empirical, but an exploratory theoretical and literature study with the primary intention of summarizing and constructing frameworks, sketching hypotheses, and identifying avenues of study.

3 DEFINITIONS AND CONCEPTUAL ANALYSES OF KEY ENTITIES AND RELATIONS

3.1 Contaminated land

Chemical 'contamination' overlaps with other types of contamination, e.g. radio-nuclides and biochemical agents such as natural toxins. In some cases, also within geographically limited hotspots, but more commonly within extensive areas of contaminated land, several forms of contamination coexist (e.g., 'mixed pollution' in radiation protection). Traditionally the focus has been on only some categories of contamination (Fig. 1). Chemical contamination also closely and dynamically interacts with physical and biological (e.g. ecological) factors, in turn affected by and underlying 'technosphere'.

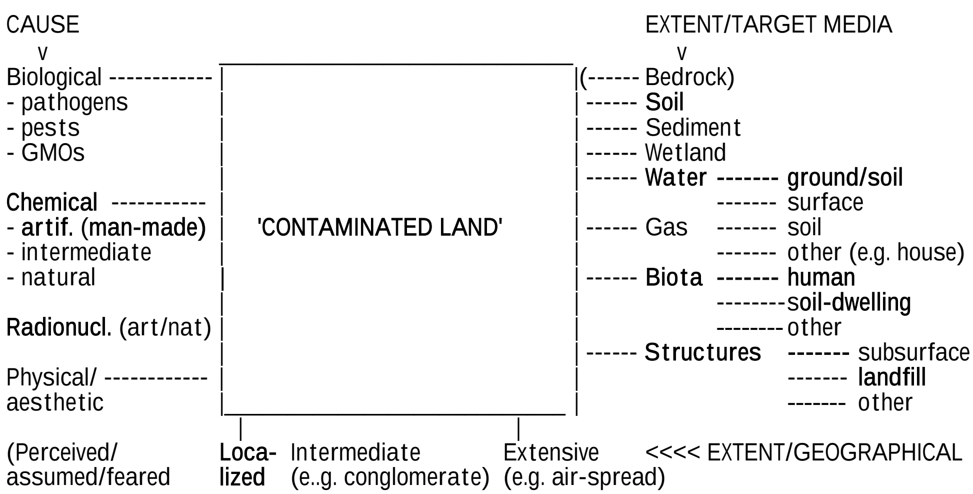

Fig.1. Schematic presentation of key categories and descriptors of land contamination, emphasizing its causes, extent and forms. The categories traditionally subject to most attention are indicated **in bold**.

Contamination of land results from many kinds of sources and causes, e.g. prolonged or accidental. Contamination frequently is the consequence of, at least in part, natural causes, while this has been seldom fully acknowledged. Indeed the distinction between natural and anthropogenic contamination is often ambiguous, e.g. with man-induced reactions and processes of natural contaminants or, *vice versa*, with natural reactions and processes affecting man-made contaminants (Fig. 1).

'Land' implies a broader scope than soil, while being more restricted in terms of compartments than a 'site'. It is however often difficult to decide whether other compartments than soil (e.g. water, sediment; buildings, not soil-dwelling biota) are (to be) included in land. Sometimes land has a very broadly inclusive connotation, standing for an entire region (or, figuratively and poetically, 'Earth').

Geographically, 'contaminated land' thus includes areas influenced by diffuse and background contamination (Fig. 1). Moreover, in a spatial continuum the heterogeneous mosaic of contamination at both intra-site and inter-site scales is to be considered. Such extended boundaries have important implications for management, as comprehensiveness also of environmental compartments is stressed. Thus, one enters management of extensive contamination punctuated by hotspots, at times building up conglomerates as e.g. in large industrial areas and complex brownfields.

3.2 Risk

'Risk' is a central concept. It is suggested that many controversies about risk management can be largely traced to variability and inconsistency in the use of the term (e.g., Lash et al. 1996). Thus, there exist many different notions of "risk based", varying by user and use context. In particular, the dimensions, qualities and other attributes of risk have to be considered (Table 1). It should be specified e.g. to whom risks are caused, by what, when, how, and what kinds. Complex, nested, indirect, cumulative, socially dependant and other hard-defined risks are encountered, as in EIA (Cooper and Sheate 2002). Particularly important from a management point of view are uncertainties (cf. Clarke and Reed 1988) and psycho-social character of risk (e.g., Dunn et al. 1994, Kroll-Smith and Crouch 1991).

Table 1. Some dimensions and attributes of risk, impact and uncertainty, with particular reference to contaminated land. Those dimensions and attributes paid most attention in RBLM are shown **in bold**.

Dimension/class of risk/impact	Attributes	Subtypes (polarities)	Examples/foci in management of contaminated land risks
Cause	agent	**contaminant**/other	cf. Fig. 1
	general type	**tech**/social/natural	manmade chemicals, imposed risks
	singularity	**single/multiple causes**	mixes; risk attributability unclear
Target	route/media	**soil/GW** etc.	cf. Fig. 1
	organism (group)	human/non-human	**biological** / social level
	organizat. level	molecul. - **indiv.** - ecosystem	community level crucial, omitted
Consequence	endpoint	toxicity (various kinds) /other	**cancer** most commonly addressed
	singularity	**single** - multiple (nested)	often multiple effects
Temporal dimension	duration	short - long	long-time/persistent/lagged
	frequency	high - low	discrete events (e.g. accidents)
Spatial dimension	geographical	**local** – global	extensive land deterioration
	general	**separate** – connected	site/conglomerate
Uncertainty	type	**data**/model; of probabil/conceq	
	level	of facts/general goals and rules	dimension often excluded
Controllability	avoidabil./reducibil.	high – low	dimension often excluded
	adapt./compensat.	high – low	dimension often excluded
Social	**acceptability/norm**	high - low; sanctioned/not	guideline value or risk benchmark
	perception	dreaded – not	dimension often excluded
	assoc. benefits	economic/other	dimension often excluded

RBLM does not explicitly address risks and management of contaminated sites. It is only understood from the context whether contaminants are in focus; also risks to or through land e.g. by physical and ecological or other biological stress, and still other risks and impacts – technical, economic, social, aesthetic – can be included. Such other risks are however as yet seldom treated in a detailed and integrated manner in connection with contaminated sites (cf. Fig. 1).

A more extensive view of risk is implied by the increasing emphasis on putting risks into context by relating them to each other and also to the benefits of accepting risks, and by comparing risks and benefits of alternatives. Risks in this connection may be defined through the probability of loss, and thus embedded in benefits. In contaminated land management, this is related to the extension of scope to address larger areas, new processes and impacts, and adjacent societal sectors and factors.

Here it is still more important that the concept "risk based" not only reflects this variety in views of risk itself, but has an even stronger and qualitatively different value- and attitude-dependant character. It can have a pretentious air, loaded with value judgments, political messages and even ideological connotations. 'Risk based' is often used to imply something superior to ‘non-risk-based’ and irrational approaches, and to convey both realism and novelty of perspective. That is, an element of symbolism and its socio-psychological and cultural determinants can be noted.

3.3 Management

'Management' includes varied activities: information, communication, negotiation, policy formulation, planning, decision-making, implementation, monitoring/control. Management extends from initial stages of risk identification and evaluation to risk avoidance, reduction and compensation; these stages and points of intervention in the field of health risks have been detailed e.g. by Health Council of the Netherlands (1996). Management also takes place at various geographical (and time) scales and on various levels, from institutional or strategic to operative or technical. Many kinds of steering instruments are used, roughly divided e.g. to knowledge-based, normative and economic ones.

Contaminated land management not only involves cleanup and other such remedial measures (and preceding diagnostics), but also prevention of contamination, and reuse of areas treated. Thus, in terms of time dimensions and operational stages, hotspot treatment extends to the whole life-cycle of (contaminated) land. In these respects, RBLM is more extensive than RBCA. In addition, cleanup is fused with active soil uses such as agriculture and construction.

Importantly, 'land management' does not restrict itself to management of contamination. However, because of the traditional split focus either on chemical contaminants or on other types of risks, e.g. geotechnical, an integration of contaminant management with other areas of land and property management is limited. For instance, many institutional and economic steering mechanisms of land management such as land use planning systems, administrative, and supports, and related legislation, have still to be brought to bear on contamination issues.

While these extensions within and in relation to management are justified to put soil contamination in a larger context, they lead to difficult questions of commensurability, acceptability, sufficiency, efficiency and integration of management goals, strategies and actions. In short, "risk based" gets new meanings when such broader concepts are included.

4 CONFUSIONS AND CONTROVERSIES IN THE USAGE OF RISK BASED LAND MANAGEMENT

4.1 General

It is argued that the usage and to some extent also the idea(l) of "risk based management" is largely an illusory, even cosmetic strive to manage risks and uncertainties and to resolve related controversies which by their nature defy formal, organized, quantifiable and (traditionally) rational approaches.

It is also argued that the talk about "risk based" management is often a rhetorical posture to give an impression of competence, responsibility and activity. Those involved in management, particularly those with interests at stake, are easily driven to assume and to position that a rational "risk based" approach is attainable without reflecting on its foundations and limits. Risk based management and its alternatives are thus presented as caricatures by both risk-averse and risk-tolerant parties.

Often the usage of "risk based" conveys an attempt to demarcate a distinction from and a superiority over people's perceptions. Typically, the advocates of "risk based" mean to say that the views of risks and management held by others (e.g. site inhabitants, laypeople, media and politics) are both less scientific and less reasonable and not based on "real risks", and significant risks in comparison with other risks. That is, 'risk based' is contrasted with 'fear based' or 'guess based'. Yet, also "risk based" management is a concept based on complex and variable valuations, preferences and considerable subjectivity, even when a scientific, rational and objective approach is claimed or implied.

On the other hand, also those requiring strict management, e.g. citizens' or environmental groups, sometimes also authorities may have rigid and vague perceptions of risks, e.g. exaggerating them in relation to other risks (including those of cleanup).

Such exaggeration, as well as downplaying, of risks frequently occurs to boost or to restrict one's role and position. Both sides may claim or deny scientific evidence, and invoke or omit other competing risks and management needs. "Risk based" may thus be used as a disguise to justify various policies, strategies and decisions, also conflicting ones.

The rigidity and superficiality of the usage of a term like RBLM, or 'Risk Based' are sometimes evident in a focus on semantics, i.e. only when these explicit terms are used is management considered to be really risk based; on the other hand, when they are used, the approach is deemed satisfactory despite the actual contents. Related to this is a lack of sense of history and of the fact that risk based management may have been described and practiced for a long time, albeit under different names. This is also often coupled with the illusion that only new concepts are good - and that they are already sufficient. This can be termed a modernist bias, and can exclude true innovativeness.

This critique does not imply that RBLM should not be striven at and developed, and that rational decision making also by formal procedures be unnecessary, undesirable or impossible. It rather illustrates the need for debunking empty ‘risk facades’ among all parties, and for extended concepts of rationality (such as communicative, e.g. Habermas 1981, 1993).

Especially with prioritization in risk management the debates center around asymmetry in bearing risks and benefits, such as whether local contamination is tackled by disproportionate resources. Asymmetry may be a problem e.g. for equity, but may be acceptable e.g. based on differences in risk and on mandates in risk management; as total integration of interests and sectors is rarely possible.

The problems, pitfalls and deficiencies of RBLM are illustrated by the fact that in many cases risks aren't really assessed or taken into account in decisions (although a cosmetic assessment and consideration may take place), e.g. by analyzing the various dimensions of risks and associated uncertainties (cf. Table 1).

4.2 Risk models as tools of thinking, reflections of prejudices and vehicles for agendas

The rise of RBLM is parallel to the increased insistence on quantitative, usually mathematic and preferably computerized models of risks (and of their management). However, even the concept 'model' is often used vaguely and rigidly. This frequently leads to over- and underestimation of the significance and of the limits of models in describing, predicting and solving problems.

Model is also used in various ways and parlances. Often only simulation models are meant, not statistical, conceptual, analogue or other models. If only e.g. quantitative models be adhered to, important dimensions may be lost. A similar attitude is seen when advocates of 'soft' and 'hard' data and methods clash (e.g. in social sciences between classical economists and adherents to qualitative and participatory methods), not realizing that neither approach is a panacea, both are needed, and would be most useful in combination and interaction.

A more crucial problem, often coupled with such limited views of models, is that they are misused to suit preconceptions and even prejudices. This is typically related to the general mode of inference; for instance, the descriptions of a phenomenon and a system by the model are regarded as too generalizable and too realistic, and mistakenly seen as predictions, even as truths. In fact it is questionable whether geoscientific models can be confirmed, validated or verified at all in the real sense of the words (e.g. Oreskes et al. 1994); instead, one may speak of model evaluation.

Models of risks and uncertainties associated with contaminated land or with land more generally are typical examples of such difficulties and limitations (and short-cut attempts), due e.g. to the many complexities and irregularities occurring in such systems and also in their management. Thus, in many cases the model outputs are hypothetical calculations and representations of risks only.

Such problems and misuses of models take place particularly when there are high stakes and strong interests in seeing the reality, in predetermined ways, e.g. in fulfilling one's expectations or obligations. Although facts and values cannot be strictly separated, one should be aware of the boundaries of their domains. Instead, in many modeling cases facts and values get mixed up in a biased and confusing fashion. Both modelers and their clients frequently fall in such traps.

The tragedy (or irony) is that by acknowledging the limitations of a model can its potential be fully utilized, and difficulties be turned into opportunities. Similarly, instead of omitting and avoiding the uncertainties involved in any model, they can be turned into allies e.g. to identify, quantify and characterize the most crucial sources of uncertainty and the most critical gaps of knowledge, thus also the most efficient ways to fill them.

5 CASES

5.1 Guideline values of contaminant levels

'Risk based' management of contaminated (soil) sites is sometimes narrowly contrasted with guideline value based cleanup goals (e.g. Höijer et al. 2000). In fact they complement each other, and both are based in varying degrees and ways on risks. Guideline values do not account for site-specific factors as fully (although some do so rather elaborately), but this does not negate the basis and need for guidelines, as initial (and also subsequent) decision criteria, nor guarantees many-sided and balanced account or risks when using alternative, allegedly 'risk-based' approaches.

There is thus a continuum of 'risk based' approaches to contaminated land management (Fig. 2). These approximate logical stages of development but the order is not clear-cut: often the 'stages' overlap; one can enter and exit at any stage; the order may be reversed, as when non-formal and qualitative approaches are included after formal and quantitative analyses e.g. in participatory decision processes; often the stages are applied simultaneously to address a risk or a problem. Also, descriptors of approaches can be mutually independent and can coexist, such as deterministic or probabilistic approaches and account for benefits (Fig. 2; see also Katsumata and Kastenberg 1998).

No approach is inherently and *a priori* 'better' than others, but all may be sufficient for a given case and purpose; all involve the general issues and pitfalls outlined above of biased concepts and reasoning. Even the 'simplest' ones may be based on complex mental maps of risks. Likewise, even the most advanced 'risk-based', e.g. quantitative probabilistic, analysis has limitations and can be misused.

Non-formal e.g. intuitive	>>>>>>>>	Formal qualitative	>>>>>	Formal semiquantitative (e.g. scoring and ranking)
û				v
Still broader/ more specific				Simple generalizing quantitative (e.g. guideline value based)
û				v
Multi-objective decision/risk analysis				(Site-)specific deterministic
û				v v
Benefit-accounting quantitative (deterministic or probabilistic)	<<<<	Benefit-accounting qualitative (options identification or cost-effectiveness)	<<<<	Quantitative uncertainty-based (from variation analysis to Monte Carlo / pdf sampling to genuinely stochastic methods

Fig. 2. Stages and levels of analytical approaches to risk based contaminated land management.

5.2 Risk models in relation to management

An example of general problems of risk models in contaminated site management is provided by the use of a site-specific model of dioxin risks at a sawmill (Höijer et al. 2001) which omitted the fact that the model (CalTOX) does not suit mixtures such as dioxins, and did not detail key transport routes, fate processes and effects. The key thing in these kinds of model application is, rather than the deficiencies of the model per se, that they are not even indicated and documented, and the structure, parameters and workings of the model are not described or even referred to so they could be checked.

In an earlier survey of risk assessments performed on contaminated soil sites in Finland (Sorvari and Assmuth 1999), great problems and deficiencies were notable in the use of models, as well as in the overall focusing and conduct of assessments and in their connections with the site investigation and remedial planning and decision making process.

Also in other cases of site assessment and cleanup decisions conclusions e.g. of the significance of risks and of management alternatives have already been set or at least implied from the start, and the task of the modeler has more or less been just to 'prove' this – instead of using the model to systematically question and refine the assumptions, data and general rationales involved. The use of models may then be degraded to a kind of a ritual, and the picture of reality cast by the model turn into a caricature. Even detailed models, such as those prescribed in RBCA standards, can thus be misused, leading to assessments and actions which are risk-based only in name.

6 DISCUSSION

It has been initially conceived and illustrated what challenges and pitfalls lie in the concept of RBLM, considering the extent and the content of each of these terms and the variability of their usage.

There certainly exist justifications for a more risk-conscious and risk-based (in many forms) view of and approach to contaminated site, contaminated land and generally land management. This is needed e.g. to avoid and alleviate problems caused by badly focused and inappropriately sized requirements and actions (these can be both over- and undersized). Thus, also RBLM is good in principle.

Still, several questions and criticisms can and ought to be directed to this and other such concepts and approaches. First, it can be asked if not all good management is risk based, even if risk would not be explicated, at least according to some standard or other such categorical and formal procedure. The answer to this evidently is that risk analytical approaches, even if not omnipotent, do add important dimensions to management especially when dealing with pressures and management challenges like toxic contamination in complex natural and technical settings. However, risks should and can be analyzed multi-dimensionally in various ways according to the situation and the purpose, including use of non-standard methodologies and terminology, and with land management particularly extending the scope and tools of assessment to cover aspects of risks not traditionally addressed such as those not related to local chemical contaminants only.

Instead, the crux of the criticism should be focused on the fact that RBLM and similar concepts are used also as euphemisms, as disguises of self-interested risk and management policy preferences, and as excuses and means to either inflate risks (and to make risk perceptions of others seem downsized) or, perhaps particularly, to belittle risks (and to make perceptions of others seem exaggerated).

That is, the meaning of RBLM and what it 'really' should be, is open to question and debate. However hard standardized to make it seem objective and respectable, it will still leave open the crucial questions of which risks and which of their dimensions and characteristics should be addressed, how they and associated uncertainties should be valued, and especially on what grounds risk and uncertainty management goals and options should be chosen, since there is no unequivocal 'scientific' answer e.g. to risk acceptability or commensurability or risk management policy choices. Largely it is a question of whether and to what extent only calculable (physical and perhaps economic) risks be included in management considerations, or also at least to some extent the multi-faceted social dimensions of risk, uncertainty and their management, e.g. allowing for the possibility of even unidentified risks and uncertainties on the basis of the precautionary principle and other such grounds.

It thus seems clear that RBLM and various versions based on the 'risk based' notion are not the panaceas they at times are presented and seen as, but have several and severe problems and limitations. Many of these are related to limited understanding of the complexity of risk and management, coupled with a desire to exaggerate the significance and promise of such approaches. In particular, the rigid but at the same time vague insistence on risk based approaches is hypothesized to be frequently associated with a tendency to downplay risks. This can often also be seen as an expression of 'expertocracy' and narrow orientation toward technical aspects of risk management instead of the wider social ones. Similarly, 'science-based' is a term often used ambiguously also to convey authority. Even when risks be exaggerated by others also claiming to base their judgments on 'real risks', due e.g. to publication bias or other socio-psychological bias toward risk inflation (Siegrist and Cvetkovich 2000 and 2001), this may be seen fundamentally as reflections of the same limited understanding of, and self-interested biased approach to, risks and risk-based management.

Regardless of the justification for such opinions it may be suggested that the differences in concepts, opinions and approaches which have been outlined above are related to fundamental philosophical, value and world-view differences. In a simplifying manner these might be characterized e.g. by the polarities rationalistic, expertise-stressing, technical and placating or conservative view on one hand, and a socially oriented, expert-suspicious, anti-technological, precaution-stressing, even alarmist view. Both have deficiencies and limitations as well as merits and legitimacy, in epistemological e.g. inference-related sense and, even more so, in a democratic sense as also 'extreme' opinions are allowed and indeed encouraged in an open society. Both address important aspects and issues of reality and justified principles and strives. Thus, they not only compete and conflict but may also converge, or define and fertilize the other, at least after antagonism in a dialectic process.

The consideration of benefits beside risks is parallel e.g. to the increasing use of risk-benefit analyses (RBA) particularly for resource allocation and prioritization in many areas of management, indeed government at large (e.g. in the US in connection with proposed laws on regulatory reform). This is important but problematic and does not cover all pertinent aspects of risks; it can also be advocated and practiced narrowly. Such views of risks may still be limited by one-sided attention to quantitative assessment and one-dimensional comparisons (cf. Roth et al. 1990). Comparisons are often based on generalizations and simplifications involving value judgments which can be questioned, e.g. when other dimensions of risks and other considerations in policies are de-emphasized. A similar phenomenon is notable in many areas of risk management, as exemplified by the narrow, simplified and self-serving comparisons of (point estimates of) risks by critics of precaution with health risks of chemicals, in what has been termed "risk revisionism" (cf. Finkel and Golding 1994). There are also other varieties of 'risk contestants' trying to plead for less (or more) stringent regulation of a particular 'own' risk by pointing out bigger (or smaller) risks regulated less (or more) in other areas, despite their incommensurability.

At any rate, several types of risk and conditions for risk management are to be addressed to allow a truly 'risk-based' approach. Other risks than contamination-related are already included in general soil protection (e.g., by consideration of soil covering, compaction, desiccation and erosion) and have also been traditionally addressed e.g. in land construction and geotechnics, landscape architecture and agricultural and forestry technology. Healey (1995) stressed the importance of detailed account for local conditions for land redevelopment, and Wernstedt et al. (1999) the consideration of land-use in remedial action. Similar general points have been expressed e.g. in connection with the debate in USA on 'rational risk reduction' and the strict requirements of some that risks and management efforts be prioritized strict on cost-benefit or cost-efficiency basis, the critics pointing out that the public may have other dimensions of problems and solutions on their mind than dollars and body counts only.

Bohnenblust and Slovic (1998) convincingly argued more generally that simple technical analysis cannot capture the complex scope of preferences or values of society and individuals. Given the need for also formal methods of decision support, technical (risk, uncertainty) analysis has to be combined with other methods better allowing for consideration of the public values, other social factors and the overall decision situation and context, including multi-dimensional and multi-objective methods. Attempts in this direction have been made also in connection with remedial action at contaminated sites (e.g., Bonano et al. 2000; Christou and Mattarelli 2000; Papazoglou et al. 2000). Also the recent r&d in socioeconomic aspects of brownfields management (e.d. De Sousa et al. 2000), as well as advanced decision analytical and support methodologies accounting for non-quantifiable factors in other relevant areas such as general soil preservation (Duke and Aull-Hyde 2000) and groundwater protection (Huang and Uri 1990) are valuable in this regard.

The implications of uncertainty and the roles of science and models are important in relation to definitions of appropriate 'risk basis' of management. The limitations of scientific knowledge have to be acknowledged and its implications to policies and decisions considering the precautionary principle (see e.g. Hagenah 1999). Risk management may be rationally based on also other premises than (natural) scientific; for a logical argumentation in a more general socio-political context see Schrader-Frechette (1991). Thus, 'political' management approaches, despite their considerable variation and limitations, need not be *a priori* inferior to 'exact' physical, technical or economic risk calculations. Instead, a political approach may in advanced and subtle ways take on board a host of other factors in decisions and actions, including normative, social and other such pragmatic and principle-level factors. Political management approaches may also be based on, and enhance, inter-actor processes e.g. of negotiation, participation, trust-building and tradeoffs. In principle, such an approach may also facilitate the explicit incorporation of and interaction with such developing scientific knowledge and formal tools, even 'hard data' and quantitative methods where they are appropriate.

7 CONCLUSIONS AND RECOMMENDATIONS

For truly efficient and sustainable - also in the sense of acceptability – management of contaminated land, broader analyses are needed of risks and uncertainties as well as management goals, options and impacts. These analyses should account for human phenomena and their interplay with nature and technology, embracing qualitative aspects and uncertainty, and linked with scientific and policy debates.

It is shown to be possible and advisable to combine such breadth with focus. This is crucial also in practical management. Such analyses should rely on, and feed to, improved assessments of knowledge acknowledging its multi-dimensional, value-laden and contextual nature, and improved concepts of management as a learning process. While such a holistic view has to be augmented by more limited assessments and management processes, a more extensive and balanced, socially and ecologically inclusive view of and approach to caring for land or indeed Earth – as an economic, ecological, but also a cultural and even spiritual resource – especially based on more humble, critical and independent thinking is urgently needed and possible.

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REFERENCES

Assmuth T, Sorvari J. Risk assessment of contaminated soil sites: pitfalls and misleads during early journey- A commentary (in Finnish). Ympäristö ja Terveys (Environ Health) 34;1(2003).

Bohnenblust H, Slovic P. Integrating technical analysis and public values in risk-based decision making. Rel Eng Syst Saf. 59;1(1998):151-9.

Bonano EJ, Apostolakis GE, Salter PF, Ghassemi A, Jennings S. Application of risk assessment and decision analysis to the evaluation, ranking and selection of environmental remediation alternatives. J Haz Mater. 71;1-3(2000):35-57.

Brun W. Subjective conceptions of uncertainty and risk. Bergen, Univ Bergen 1995.

Byrne P. Risk, uncertainty and decision-making in property development. London, Spon 1984.

Christou MD, Mattarelli M. Land-use planning in the vicinity of chemical sites: Risk-informed decision making at a local community level. J Haz Mater. 78;1-3(Nov 2000):191-222.

Clarke HR, Reed WJ. A stochastic analysis of land development timing and property valuation. Reg Sci Urban Econ. 18;3(1988):357-81.

Cooper LM, Sheate WR. Cumulative effects assessment - A review of UK environmental impact statements. Environ Impact Assess Rev. 22;4(2002):415-39.

Denneman C. The Netherlands. In: Ferguson CC, Kasamas H (eds.) Risk assessment for contaminated sites in Europe. Vol. 2. Policy frameworks. LQM Press, Nottingham. Pp. 107-21.

De Sousa C. Brownfield Redevelopment versus Greenfield Development: A Private Sector Perspective on the Costs and Risks Associated

with Brownfield Redevelopment in the Greater Toronto Area. J Environ Planning Manage. 43;6(2000):831-53.
Duke JM, Aull-Hyde R. Identifying public preferences for land preservation using the analytic hierarchy process. Ecol Econ. 42;1-2(2002):131-45.
Dunn JR, Taylor SM, Elliott SJ, Walter SD. Psychosocial effects of PCB contamination and remediation: the case of Smithville, Ontario. Soc Sci Med. 39;8(1994):1093-104.
Ferguson C. et al. (eds.) 1998. Risk assessment for contaminated sites in Europe. Vol 1: Scientific basis. LQM Press, Nottingham.
Finkel AM. Towards less misleading comparisons of uncertain risks: The example of Alar and afiatoxin. Environ Health Perspect. 103(1995):376.
Finkel AM. Comparing risks thoughtfully. Risk - Health, Safety & Environment 7(1996):325-46.
Finkel AM, Golding D (eds.) Worst Things First? The Debate over Risk-Based National Environmental Priorities 1994.
Geltman E. Recycling land: encouraging the redevelopment of contaminated property. Natural Resources Environ. 10(1996):3–10.
Greenberg M, Lewis MJ. Brownfields redevelopment, preferences and public involvement: A case study of an ethnically mixed neighbourhood. Urban Studies 37;13(2000):2501-14.
Habermas J. Theorie des kommunikativen Handelns. Frankfurt/M, Suhrkamp 1981. 1167 p.
Habermas J. Justification and application : remarks on discourse ethics. Cambridge, MA, MIT Press 1993. 197 p. Studies in contemporary German social thought. (Translated by Cronin C).
Hagenah E. A regulatory view on science and predictive models. Environ Pollut. 100;1-3(1999):13-8.
Healey P. The institutional challenge for sustainable urban regeneration. Cities 12;4(1995):221-30.
Health Council of the Netherlands. Risk is more than just a number : reflections on the development of the environmental risk management approach. The Hague, Health Council of the Netherlands 1996. 120 s. Gesondheidsraad E 1996.
Hollins M, Percy S. Environmental liability for contaminated land -- towards a European consensus. Land Use Pol. 15;2(1998):119-33.
Huang W-Y, Uri ND. Optimal policies for protecting the quality of groundwater. Resources Energy 11;4(1990):371-94.
Höijer L, Valo R, Koskinen AL. The risk caused by contaminated sites: an example of quantitative health risk assessment (in Finnish). Ympäristö ja Terveys (Environ Health) 32;9(2001):68-72.
Katsumata PT, Kastenberg WE. On using residual risk to assess the cost effectiveness and health protectiveness of remedy selection at superfund sites. Rel Eng System Saf. 62;1-2(1998):131-51.
Kavanaugh MC. An overview of the management of contaminated sites in the US: the conflict between technology and public policy. Water Sci Tech. 34;7-8(1996):275-83.
Keuzenkamp KW, von Meijenfeldt HG, Roels JM. Soil protection policy in the Netherlands, the second decade. In: Arendt F, van den Brink WJ (eds.), Contaminated Soil ´90, pp. 3-10. Kluwer Acad Publ., Dordrecht / Boston / London 1990.
Khan FI, Husain T. Risk-based monitored natural attenuation — a case study. J Haz Mater. 85;3(2001):243-72.
Kroll-Smith JS, Couch SR. As if exposure to toxins were not enough: the social and cultural system as a secondary stressor. Environ Health Perspect. 95(1991):61-6.
Lash S, Szerszynski B, Wynne B. (eds.) Risk, environment and modernity : towards a new ecology. London, SAGE Publications Ltd. 1996.
McCarthy L. The brownfield dual land-use policy challenge: reducing barriers to private redevelopment while connecting reuse to broader community goals. Land Use Pol. 19;4(2002):287-96.
Merkhofer MW. Decision science and social risk management : a comparative evaluation of cost-benefit analysis, decision analysis, and other formal decision-aiding approaches**.** Dordrecht, Reidel 1987.
Meyer PB, Lyons TS. Lessons from private sector brownfield redevelopers: Planning public support for urban regeneration. J Am Planning Assoc. 66;1(2000):46-57.
Oreskes N, Shrader-Frechette K, Belitz K. Verification, validation, and confirmation of numerical models in the, earth sciences. Science 263 (1994):641-46.
Papazoglou IA, Bonanos GS, Nivolianitou ZS, Duijm NJ, Rasmussen B. Supporting decision makers in land use planning around chemical sites. Case study: expansion of an oil refinery. J Haz Mater. 71;1-3(Jan 2000):343-73.
Roth E et al. What do we know about making risk comparisons? Risk Anal. 10(1990):375-6.
Shrader-Frechette KS. Risk and rationality : philosophical foundations for populist reforms**.** Berkeley, Univ California Press 1991.
Siegrist M, Cvetkovich G. Better negative than positive? Evidence of a bias for negative information about possible health dangers. Risk Anal. 21;1(2001):199-206.
Siegrist M, Cvetkovich G. Perception of hazards: the role of social trust and knowledge Risk Anal. 20;5(2000):713-9.
Slovic P. Perception of risk. Science 236;4799(1987):280-5.
Slovic P. Trust, emotion, sex, politics, and science: surveying the risk-assessment battlefield. Risk Anal. 19;4(1999):689-701.
Smith AH, Sciortino S, Goeden H, Wright CC. Consideration of background exposures in the management of hazardous waste sites: a new approach to risk assessment. Risk Anal. 16;5(1996):619-25.
Sorvari J, Assmuth T. 1999. Site-specific risk assessment of contaminated soils – situation in Finland (in Finnish, with English abstract). Finn Environ Inst Mimeograph 147(1999). 38 p.
Wernstedt K, Hersh R, Probst K. Grounding hazardous waste cleanups: a promising remedy? Land Use Pol. 16;1(1999):45-55.

A RISKY BUSINESS: FACTORS FOR CONSULTANTS TO CONSIDER WHEN ADVISING STAKEHOLDERS WHETHER TO PROGRESS BEYOND USE OF TRIGGER VALUES TO DEVELOPMENT OF SITE-SPECIFIC ASSESSMENT CRITERIA (WITH SPECIAL REFERENCE TO THE UK SITUATION)

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Introduction and Context

The Department for the Environment, Food and Rural Affairs (DEFRA) and the Environment Agency for England and Wales launched the UK's first suite of Soil Guideline Values (SGVs), derived from the Contaminated Land Exposure Assessment (CLEA) model early in 2002. Each SGV was set out in a short, individual document describing the fate and transport processes particularly relevant to that substance (1) together with the derivation of the SGV. In addition, a separate toxicological report was provided for each substance, setting out the derivation of the Health Criteria Values and describing background exposure (2). The SGVs were accompanied by supporting documentation (3,4,5,6), including CLR9 (5), which is a description of the general principles underlying the UK toxicological approach and CLR10 (6), a description of the technical basis and algorithms underpinning the model.

The SGVs were the UK's first set of trigger values for human health risks from contaminated soil developed strictly within the source-pathway-receptor framework. The SGVs are intended to be intervention values in that they trigger the need for either more detailed quantitative risk assessment or remediation. They support Part IIA of the 1990 Environmental Protection Act, which addresses contaminated land, and are also appropriate for use under planning applications. Past sets of environmental receptors did not have a transparent basis (for instance toxicological benchmark, critical receptor, relevant pathways), upon which a risk assessor could develop site-specific assessment criteria. Therefore, risk assessors providing advice to clients (e.g. regulators such as local authorities or commercial clients such as problem holders or land developers) had three basic options if soil concentrations exceeded the generic assessment criteria:

- Progress directly to remediation;
- Adopt a pragmatic adaptation of the existing values, which therefore had no scientific basis (e.g. multiplying by a factor); or
- Derive site-specific assessment criteria, completely unrelated to the existing generic assessment criteria.

In the absence of a transparent and coherent framework, the option chosen would often be dependent on the level of understanding and preference of the local regulator as much as a cost-benefit analysis.

Risk assessors have a clear framework within which to operate now that the CLEA SGVs are available, together with the accompanying documentation. This makes certain aspects of advising clients easier. For instance, when considering contaminant concentrations that exceed the SGVs, it is easy to check whether the Conceptual Model inherent within the CLEA model realistically matches the Conceptual Model for the site. It also becomes clear which pathways are the risk drivers and how this could be used in a risk management context. However, certain aspects of providing advice on whether to remediate or progress to further tiers of risk assessment have become more difficult. For instance for substances for which SGVs are available, certain parameters cannot be altered because they have been approved by a number of government departments and agencies including the Environment Agency, the Scotland Environment Protection Agency, DEFRA, the Department of Health and the Food Standards Agency and strong justification is needed to depart from them. These include the toxicological benchmarks, critical receptors for certain land uses, food consumption rates and exposure and averaging periods cannot be altered Sometimes these decisions, together with policy decisions such as the inclusion of background sources of exposure for threshold contaminants, are the dominant factors which result in a particular SGV being low, rather than issues surrounding the Conceptual Model. This can sometimes prevent or hinder the full benefit of the role that site-specific assessment criteria can potentially play.

Introduction and Context Continued:

Recommending to a client that further detailed quantitative risk assessment should be undertaken, rather than direct progression to remediation, is never an easy option for a consultant. This is particularly true in the field of human health risk assessment where traditionally the easiest option for remediation has been seen as excavation and disposal, with the consequent removal of liability. Human health risk assessment of soils is viewed with considerable suspicion, far more so than in the arena of groundwater risk assessment, probably because of the acknowledged logistical difficulties and expense involved with the treatment of a contaminated aquifer. Generic assessment criteria are often viewed as "look up" tables for establishing whether remediation is required, without detailed reference to the underpinning Conceptual Model. Further detailed quantitative risk assessment has a number of disadvantages, including further delay to a decision and residual risk. Additionally, there is no guarantee that further detailed quantitative risk assessment will produce the desired result. This may lead to a loss of credibility for the consultant who has recommended the extra time and expenditure, only to establish that remediation is still necessary. As this may lead to loss of repeat business, specialist risk assessors may be unpopular with project managers and detailed quantitative risk assessment is often the last bastion for sites for which other available options have been explored.

However, increasingly the use of further detailed quantitative risk assessment may become invaluable in the UK, if not actually required. Development of SGVs for application under Part IIA applies to current land use, in contrast to the previous UK trigger levels of the ICRCL guidelines, which were designed for redevelopment purposes. The Landfill Directive will also have the effect of making excavation and disposal more difficult. It may therefore be in the interest of stakeholders to pursue detailed quantitative risk assessment and for consultants to be able to offer advice on circumstances in which this process has a good chance of establishing no requirement for remediation. While there will never be a cast-iron guarantee that this will be the case, there are a number of factors specific to the site and substance(s) involved that make this situation more likely. It is vital for risk assessors to have a good appreciation of these factors, when advising stakeholders on the requirement for progressing directly to remediation or to undertake further assessment. There can then be an open discussion about the level of risk with respect to expense, time frame and perception that the stakeholder(s) are prepared to accept. This paper is not intended to be prescriptive, exhaustive or ground-breaking but to explore some of the factors effecting expense, time and perception of quantitative risk assessment. While many may appear obvious, it is easy to overlook one or more when faced with pressure to provide an appropriate solution in a tight time frame with limited resources. Some of the factors to be considered include the following:

- The management context;
- Magnitude by which soil concentrations exceed the SGVs; and.
- similarity between Conceptual Model for site in question and the Conceptual Model underpinning the SGVs, particularly related to (i) soil conditions, (ii) position and nature of source, and (iii) substance-specific fate and transport assumptions

A difference in any one of the Conceptual Model descriptions listed above may have a material effect on the key pathways driving the risk.

The Management Context

The site circumstances (sometimes referred to in the UK as the management context) yield a number of relevant issues. Two of the most important is whether the site is currently occupied or is undergoing development. Often stakeholders are more prepared to consider further risk assessment when a site is occupied. This is not because exposure to contamination is less important, but because of the magnitude of the decision to designate a site as "contaminated" under Part IIA of the Environmental Protection Act 1990. This carries a number of emotional, practical and financial implications, and therefore the risk involved in the expenditure of further resources to determine whether a problem actually exists may be considered worthwhile. Indeed in this situation, the problem-holder often approaches a specialist risk assessor to request detailed quantitative risk assessment, though he/she is aware that the likely outcome may not be favourable. Even in redevelopment situations, if the problem-holder is a local authority that has had difficulty finding a suitable location for a particular land-use such as an allotment, they may be prepared to expend resources in further risk assessment because they have limited resources for remediation.

The Management Context Continued:

In contrast, a commercial client seeking to develop brownfield land is likely to be less ready to take such a risk. This feeling may be influenced by a number of factors including: (i) the overall timescale and budget available for risk assessment and remediation, (ii) considerations of long-term liability (especially if risk averse financial institutions are involved in the project), and (iii) the flexibility or otherwise to use the site for another, less sensitive purpose. Another consideration that may influence the risk assessor (even if strictly speaking they should not) is the strict regulatory translation and level of risk assessment comfort owned by the local regulator. An area of land may lie within the jurisdiction of a well-informed regulator that is interested in further risk assessment that may reduce the uncertainty of the behaviour of soil contaminants on a particular site. Conversely, the local regulator may feel more comfortable with a strict adherence to the generic assessment criteria. In a Part IIA situation the Statutory Guidance (7) states that "the local authority should be prepared to reconsider any determination based on such use of guideline values if it is demonstrated to the authority's satisfaction that under some more appropriate method of assessing the risks the local authority would not have determined that the land appeared to be contaminated land." However, considerable risk may be attached to the phrase "to the authority's satisfaction" and there may be situations when the problem-holder would rather avoid protracted negotiations. Consultants therefore need to tailor the advice they give to their clients, in order to avoid excessive expenditure of time and money.

It may appear obvious but it is worth stating that if a site is to be redeveloped, it is the Conceptual Model for the finished site that should be borne in mind. For example, if soil is to be added or removed from the site for the purpose of leveling (rather than as an explicit remedial measure), this will bring contamination further away from or closer to the surface than at the time of the initial site investigation. It is the final depth that should be compared to the Conceptual Model within generic assessment criteria such as SGVs. Equally, if pH or soil organic matter content influence the plant uptake algorithms, but it is likely that lime or compost may be added to topsoil to ameliorate conditions for plant growth, the likely final soil conditions should be taken into account.

In the context of redevelopment, timescale may be critical. For instance, if plant uptake is the major exposure pathway for a residential or allotment scenario (e.g. in the UK cadmium SGV), the risk assessor may wish to recommend that concentrations within appropriate garden vegetables are actually sampled. It is, of course, unlikely that there will be vegetables growing on a site that is yet to be redeveloped. In such a situation, pot trials are a possibility but the client should be advised up-front of the timescales involved in planting, harvesting and analysis (likely to be a few months, rather than a few weeks).

Other aspects of the management context salient to whether further risk assessment is justified when a site is being redeveloped include whether the site is sufficiently large to produce returns for extra risk assessment, and whether the spatial distribution of the contaminant(s) of concern are relatively homogeneous. If only one or two houses are to be built on a site, a developer may not consider it overly onerous to import clean cover; they may, however, feel rather differently if the site could be developed for several hundred houses. In the UK it is becoming more common to recommend bioaccessibility testing for natural arsenic contamination. This is because concentrations are usually relatively uniform across a site and the behaviour within the soil matrix is likely to be similar. Thus random samples may be considered representative of the arsenic contamination. The situation is somewhat different where there are small hotspots of anthropogenic arsenic contamination, which may have different sources and different behaviour within the soil.

Magnitude of Exceedance

Once the site circumstances have been taken into account, careful weighing-up of scientific considerations is also required. For instance, the magnitude by which the concentrations in soil exceed the SGVs is very important. If there is only a slight exceedance of SGVs, there is a good chance that refinement of the Conceptual Model may result in the derivation of site-specific assessment criteria that are higher than the relevant site concentrations. However, as the exceedance increases, so does the likelihood that the development of site-specific assessment criteria will still demonstrate a significant risk, and that remediation is required.

Refining the Conceptual Model-Assessment of Key Risk Drivers

It is important for the risk assessor to identify the key pathway(s) within the generic assessment criteria that is/are contributing the most to the potential exposure. This will prevent the collation of additional information, especially if extra sampling and/or analysis is involved, to refine aspects of the Conceptual Model that will make little difference to the site-specific assessment criteria derived (and the consequent expenditure for the client).

Plant uptake will only be relevant within the residential and allotments scenarios. The SGV reports should be consulted to ascertain whether plant uptake is a dominant or significant contributor to exposure for particular substances. For instance, for the current set of SGV reports plant uptake is a strong risk driver for cadmium and selenium. As yet, no SGV reports for organic contaminants have been produced for the UK. However, it may also prove to be important for some of the non-volatile and semi volatile organic compounds, dependent on their physico-chemical properties and the plant uptake algorithm selected. On the other hand, it is less likely to constitute plant uptake as an important pathway for highly volatile compounds, where the inhalation pathways might be expected to drive the risk. A further critical point to bear in mind is that the maximum possible site-specific assessment criteria could rise from refinement of the plant uptake pathway alone is the SGV for the residential-without-plant uptake scenario. Indeed it is unlikely for this value to rise to this extent because some plant uptake would still be expected, even if less than predicted by a conservative generic assessment algorithm.

It is likely to be only worthwhile refining aspects of the Conceptual Model for the outdoor air inhalation pathway for volatile organic contaminants. This is due to semi-volatile organic contaminants being more dominated by soil ingestion and plant uptake (unless the health criteria for the inhalation pathways are much lower than those for the oral pathways). Equally, there is no point in considering the outdoor pathway further for volatile contaminants in land use scenarios where an indoor vapour intrusion pathway exists (e.g. residential). In such a situation, the indoor air pathway will typically contribute over 90% of the total exposure. On the other hand, for a land use scenario such as allotments, it may merit further consideration.

For standard land use scenarios, inhalation of dust is usually considered a very minor contributor. This may, however, change for areas where there is movement of vehicles over bare soil (e.g. motorbike scrambling). CLR10 explicitly states that the SGVs are not applicable to such scenarios.

Refining the Conceptual Model-the Source Term

The SGVs assume that contamination is present within the top 10 cm of soil for direct contact pathways, within the top 50 cm for plant uptake, at 1m depth for outdoor inhalation, and directly beneath the footprint of the house for indoor inhalation. It is still relatively common practice for the maximum soil concentration for a site to be compared to the SGV for initial screening, regardless of depth. If sampling and analysis at a variety of depths has already been undertaken, a little extra data analysis may show that the majority of contamination is at depth, reducing or minimising the likelihood of exposure. If insufficient samples have been taken at relevant depths to establish this, the risk assessor should clearly explain the extent and cost of the extra sampling required in order to make a decision (and suggest that future sampling schedules for other sites are designed to provide the necessary information in the first instance, of much of the cost involved is associated with the personnel attending the site).

The Conceptual Model applied in development of the SGVs assumes that the contaminated area of a site is 15 m wide in the prevailing wind direction. A robust site investigation may provide information to show that the contaminated area is actually smaller than this, allowing the risk assessor to perform a detailed quantitative risk assessment. While this may yield results in certain scenarios, it is important to remember that this data is only used in the outdoor inhalation of organic soil vapours pathway.

In a development situation, if it is known that there is only a small area of organic contamination at depth and some flexibility exists in the site lay out, a plan may be generated that avoids placing buildings in the vicinity of this area. In this case, there would be a strong justification for the recommendation to undertake a detailed quantitative risk assessment, using an appropriate tool since the SGVs will always contain the conservative assumption, appropriate for generic assessment criteria that contamination is directly beneath the house footprint.

Refining the Conceptual Model-the Source Term Continued:

Certain assumptions are made about the soil conditions in the derivation of the SGVs. Much of this information is likely to have been routinely collected as part of the chemical and geotechnical investigation. For certain substances and land use scenarios, it may be worthwhile reviewing the data and comparing it to the SGV assumptions to determine whether a detailed quantitative risk assessment is likely to show a reduced potential for exposure, without the need to gather any further data. For instance, the SGVs are derived for a "sandy soil" as defined in CLR10. For metal contaminants, only the inhalation of dust pathways is affected by the soil type. As these are minor exposure pathways, further detailed quantitative risk assessment is not justified. However for volatile organic contaminants, if the soil type at relevant depths is for a different soil type such as clay, the site-specific assessment criteria derived may be much higher than the SGVs because exposure via the inhalation of soil vapours will be considerably reduced.

Refining the Conceptual Model - Differences in Land Use

SGVs are currently provided for the following scenarios:

- Residential (with and without plant uptake);
- Commercial and industrial; and
- Allotments.

Unlike the previous ICRCL trigger values, there are no SGVs for hard cover areas such as car parks. Provided that the hard cover is continuous and thick enough to prevent the passage of vapour, there will be no human health pathways. It is, however, important for all parties to remember that other receptors such as controlled water and ecosystems need consideration. Furthermore, stakeholders should be clearly advised that long-term liabilities and residual risk remain if the land is further developed in the future. There are currently no SGVs for the "parks, playing fields, and open spaces" scenario. It is possible to use the SGVs for "residential without plant uptake" scenario as a preliminary screening process. However, when SGVs are published for volatile organic contaminants, and if soil concentrations exceed the "residential without plant uptake" SGV, there will be strong justification for a risk assessor to use the CLEA model or other appropriate tools to exclude the indoor inhalation pathway. Further, if the park in question is not part of a residential development, it is likely that there will be less exposure of young children (normally considered the critical receptor for the "residential land use" scenario). As the patterns of use will be rather different for those prevailing in a residential setting, there may be some justification in conducting a further detailed quantitative risk assessment.

Refining Fate and Transport Modelling

Introduction

If initial comparison between the Conceptual Model applied to develop the SGVs and the Conceptual Model for the site in question, does not reveal any significant differences, it is sometimes possible to gather further data to refine the fate and transport algorithms for some exposure pathways. Measurement of contaminant concentrations in plant material and indoor or outdoor air may be used directly to estimate potential exposure. Providing it is conducted correctly, the results will usually have greater credence to a regulator than model predictions. However, the recommendation to conduct this level of detailed quantitative risk assessment is not an easy option for a risk assessor. Measurement may be expensive and entail further delays in a development scenario. There is still no guarantee that analysis will show that uptake is less than predicted. In this situation it is even more important that the risk assessor involves all stakeholders (especially their client) in a process of comparing the costs and benefits of further risk assessment as opposed to progressing directly to remediation. For instance, in the situation where a problem-holder wishes to dispose of a site for redevelopment, the outputs of a further detailed quantitative risk assessment may enable them to obtain a better selling price. In this situation, additional analytical costs may be minor compared to a potential improvement in selling price. However, frequently this may be balanced against the need to provide bidders with available information within a tight time frame. Moreover, the seller may wish to minimise their long-term risks by simply providing factual information about the site and allowing developers to perform their own risk assessment.

Refining Fate and Transport Modelling Continued:

They may also not have very much information about the way in which the site will be developed, making it difficult for the risk assessor to develop a coherent Conceptual Model applying the appropriate land use. Every client is different, where a risk assessor does not have a personal relationship with a particular client, he or she can learn a great deal by working with a dedicated project manager who is fully apprised of the client's aims and objectives.

Assessment of Risk Drivers

A major substance-specific consideration is whether it is likely that more accurate information may be obtained about the pathway(s) that are (or may become) the risk driver(s). Where fate and transport algorithms have been fundamental to the derivation of the SGVs, it is important to consider whether they are likely to over-predict concentrations on the site in question. Sometimes this will apply particularly to an exposure pathway, and not just to an individual contaminant. Careful reading of the available guidance in CLR10 and the individual SGV reports will help to inform the decision of whether to gather further data. In some cases running a sensitivity analysis may help the assessor determine whether further collation of site-specific data is worthwhile.

Vapour Intrusion

For example, the uncertainties involved in the vapour intrusion pathway are very high and the algorithms in risk assessment tools are usually considered to be conservative (although with little collected data to validate this assumption). The algorithm for vapour intrusion described within CLR10 (6) assumes certain air-exchange rates and building dimensions. It also assumes the source is directly beneath a building, does not consider biodegradation during the contaminant migration through the soil, and assumes that the source emission or release is constant with time and concentration (e.g. the volatilisation potential and concentration does not change with time). Therefore for a volatile contaminant, where the indoor air pathway is usually the risk driver, the risk assessor may consider the risks of advising a client that collecting measured data for an existing development may result in a less stringent soil assessment criterion. Clearly building decommissioning takes place in a redevelopment situation. If buildings are eminently scheduled for demolition, it is important for risk assessors to obtain measured data before this occurs, together with information on the building dimensions. Where buildings are not present, it may be possible to collate measured site-specific data relevant to the degradation rate of the soil contaminants. If a groundwater risk assessment is being carried out, this information may be required for this purpose. Measurements of this type will need to be gathered over a considerable time period, entailing a delay to the development process and a level of uncertainty which may not be acceptable to some stakeholders. A review of literature values for degradation rates for similar site conditions may inform the decision of whether or not to proceed but may not be used in place of measured data.

Plant Uptake

For the plant uptake pathway, the risks entailed in the collation of further data are likely to be high, especially in a redevelopment context. Analysis of vegetable material is costly, and laboratories that are accredited to perform food analysis often have lengthy waiting lists. If vegetables have not yet been grown on the site, pot plant trials are expensive, costly and generate considerable uncertainty. Further, prediction of plant uptake within the SGVs will usually be based on a decision from an existing data set; for example, the current set of metal SGVs are based on measured data in garden vegetables. There may not be a high level of data available on whether the soil conditions on the site in question are similar to those within this dataset. The risks of proceeding may be lower when the dataset used to derive generic assessment criteria is poor than when the dataset is good. This is because when there is little information, the soil: vegetable concentration ratio selected is likely to be from the upper end of the dataset). For instance the dataset upon which the plant uptake algorithm for the cadmium SGV is better than the dataset available for the derivation of the selenium SGV. The risks will also be lower if other conditions at the site which may not have been considered when defining the dataset used for the SGVs are known to mitigate against the uptake of contaminant. Examples include Cation Exchange Concentration, concentrations of other substances, pH and soil organic matter content.

Soil Ingestion

If soil ingestion is the major contributor to exposure, two major uncertainties to consider are soil ingestion rates and the bioaccessibility of the contaminant in the soil matrix. It is infeasible to gather site-specific information about soil ingestion rates because of the inter and intra individual variability in children's behaviour.

Refining Fate and Transport Modelling Continued:

The Department of Health policy decision is that it should be assumed initially that all contamination within soil or other media enters the human body. The exception is lead because there is greater knowledge available about the relationship between soil concentrations and actual exposure. However, CLR7 states that: "A local authority will also need to consider the local context when using Soil Guideline Values. If a substance occurs naturally at high concentrations in a locality, as a result, for example of the mineralogy of the subsoil, then the local authority may wish to consider whether a site-specific risk assessment would be a more appropriate way to proceed. This would allow the authority to consider matters such as the bioavailability of the substance and local receptor behaviour and characteristics (3)."

The risk assessor may decide to advise their client to explore the bioaccessibility option. Issues to be considered include the uncertainties involved in such testing and the acceptability or otherwise to the local regulator). Furthermore there are no guarantees that this will demonstrate that the substance has a sufficiently low bioaccessibility resulting in higher site-specific assessment criteria compared with the site concentrations. This could result in a client laying out further resources on testing and still ultimately having to pay for remediation. The risks of this occurring increase where the soil concentrations significantly exceed the SGV. It is important to review the dataset carefully before recommending this option, especially where the profile across the site varies.

Another factor to assess is whether exposure from another pathway such as plant uptake is a significant contributor, or may become so if exposure from soil ingestion is reduced. This can be assessed with relative ease by running the CLEA model with the soil ingestion removed to establish the sensitivity of the assessment criterion. If the site concentrations are not far in excess of this criterion, then it is likely that unnecessary amount of money will be expended to pursue this option.

Another risk factor for the assessor is when little is known about the origin of the contamination. In some areas of the UK with high natural arsenic, for instance, there is a sufficient body of bioaccessibility testing to inform the likely result. In other areas of the country, much less work has been conducted. Moreover, even less information is available about other contaminants, and the bioaccessibility of anthropogenic contamination that is likely to vary widely in form and availability. It is also important for the risk assessor to establish whether the toxicological benchmark is derived from a study where the contaminant was administered in a form likely to be more available than soil (such as water) or in a matrix where bioavailability was already limited (such as food or soil). This information is available within the individual toxicological reports (2).

Conclusion

Involvement of the risk assessor at an early stage of a project means that much of the appropriate data for refining the Conceptual Model at a later stage of detailed quantitative risk assessment is likely to have already been collected, reducing the need for additional expenditure. Their continued involvement throughout the lifetime of a project will help to ensure that, as additional data becomes available, the Conceptual model is continually refined. The assumptions behind the derivation of the SGVs are fully laid out within CLR10 and the SGV reports. The risk assessor's increased knowledge of these assumptions (and those behind any other set of generic assessment criteria), the more likely it is that they will be able to present to a client on a case-by-case basis with a reasoned argument for whether conducting further detailed quantitative risk assessment is likely to be beneficial or not. The importance of not understating the risks to the stakeholders should not be underestimated. Though there will never be a guarantee that detailed quantitative risk assessment will show that remediation is unnecessary, consideration of the factors above, in conjunction with the guidance, should reduce the odds considerably in conducting a detailed quantitative risk assessment that is not favourably received by the client. In some cases, conducting a sensitivity analysis will help to show the stakeholders the possible benefit that may be refined from gathering further specific items of data. Furthermore, it should ensure that where further gathering of data is necessary, it is targeted at those areas of the Conceptual Model, where refinement is most likely to yield improved results. This will help to avoid unnecessary expenditure of the client's money, and ultimately increase confidence in the risk assessment process.

Acknowledgement

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References

1) Department for the Environment, Food and Rural Affairs (2002). Assessment of risks to human health from land contamination: an overview of the development of Soil Guideline Values and related research. R & D Publication CLR7. Available for downloading from www.defra.gov.uk.

2) Department for the Environment, Food and Rural Affairs (2002). Potential contaminants for the assessment of land. R & D Publication CLR8. Available for downloading from www.defra.gov.uk.

3) Department for the Environment, Food and Rural Affairs (2002). Contaminants in soil: collation of toxicological data and intake values for human. <chemical X>. R & D Publication TOX series. Available for downloading from www.defra.gov.uk.

4) Department for the Environment, Food and Rural Affairs (2002). Soil Guideline Values for <chemical X> contamination. R & D Publication SGV series. Available for downloading from www.defra.gov.uk.

5) Department for the Environment, Food and Rural Affairs (2002). Contaminants in soil: collation of toxicological data and intake values for humans. R & D Publication CLR9. Available for downloading from www.defra.gov.uk.

6) Department for the Environment, Food and Rural Affairs (2002). The Contaminated Land Exposure Assessment model (CLEA): technical basis and algorithms. R & D Publication CLR10. Available for downloading from www.defra.gov.uk.

7) Department of the Environment, Transport and the Regions (2000). Environmental Protection Act 1990: Part IIA. Contaminated Land Circular 02/2000.HMSO, London, ISBN 0 11 753544 3.

INVOLVING LAY AUDIENCES IN ENVIRONMENTAL RISK ASSESSMENTS

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Abstract

This paper summarises the findings of preliminary research into participatory risk assessment. The research aim was to provide risk assessment practitioners with piloted and workable mechanisms for involving non-specialists in appropriate aspects of risk assessment work. These issues are of relevance internationally because the risk assessments that support decisions on land contamination, among other environmental pollution issues, are increasingly in the public domain and discussed within communities dealing with historically contaminated land. The development of more deliberative techniques for involving the public in the decision-making process can potentially benefit regulators in terms of quality of decisions reached and the trust gained with the public. These approaches offer the potential to increase scientific literacy amongst the public and enable us to have greater ownership of decisions made (DEFRA *et al.*, 2000).

1. Introduction

The way we make decisions on environmental risk is changing. There is growing public interest in, and engagement with the process of environmental decision-making, an increasing expectation of access to the technical documents and judgements of technical experts that support decisions on risk, and increased public scrutiny of the risk work of companies and regulators (Green Alliance, 2000; House of Lords, 2000). In general, stakeholders and publics expect to be consulted on decisions that affect them and wish to understand, and indeed influence the outcomes.

The regeneration of contaminated land has always required a multi- and trans-disciplinary approach (Assmuth, 1998) and increasingly, scientists, engineers, planners and lawyers are turning to the social sciences for a re-interpretation of the issues historically viewed as driven by technological and economic concerns. We are gaining valuable insights into how we might involve others in decision-making and into issues of equity and the perceptions and reporting of risk (Fischer, 1993; Apostolakis and Pickett, 1988; Petts, 2000). The interpretation and communication of an environmental risk assessment often plays a key role in the decisions that are made on land contamination (Petts, 1994; SNIFFER, 1999). Historically a technical preserve, the new agenda on risk-based land management (RBLM) is requiring us to consider how the risk assessment process now might itself be opened up for non-expert audiences (Homan et al., 2001; Pollard *et al.*, 2001).

2. Methodology

This research has been transdisciplinary and involved contributors from regulatory, academic and practitioner communities. We have addressed the project aim through (i) a review of the open and grey literature and practical experience of participatory risk assessment; (ii) a survey of Environment Agency staff to establish how public participation is perceived and to assemble experiences of involving the public in environmental decision-making; (iii) a survey of specialist and non-specialist stakeholders to understand how they might be more effectively involved in decision-making processes involving risk issues; (iv) a characterisation of decisions involving risk made by the Environment Agency so as to understand current practice on, and potential for, involvement of the public in different decision contexts.

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Our research findings, which have relevance to a range of decision contexts including those related to land contamination, have allowed us to (i) design and pilot a simulation exercise to test a possible method of participatory risk assessment, particularly directed to the early stages of scoping out the issues associated with a generalised environmental permit; and (ii) develop guidelines on good practice for people considering public participation in environmental risk decisions.

3. Study Results

3.1 Synthesis of the literature on participation in risk assessment

Risk assessment is increasingly viewed in participatory terms, in response to the 'risk society' debate (Beck, 1992), the evidence from the risk communication literature, the environmental justice agenda, and a growing understanding of scientific values. There are official calls for increased stakeholder involvement (DEFRA *et al.,* 2000) from 'problem definition' or 'framing', through to the evaluation of risk estimates. The transition to a 'right-to-know' society is requiring greater public access to these assessments which, in turn, are increasingly being discussed in public.

There is evident difficulty in defining risk decisions, and in practice caution is needed in viewing public participation as being a requirement limited to the risk assessment that informs the overall decision. In practice, it is rare that risk issues can be separated from the broader environmental, social and economic elements of decisions. Furthermore, examination of the decision contexts in which the Environment Agency is involved (Pollard, 2001) reveals it is also rare that environmental regulators are the sole decision-maker, or use risk assessments in isolation as the only decision tool.

Currently, the Agency has neither routinely nor directly involved people in deliberative processes related to decisions that involve formal risk assessments, although it has engaged people widely in standard consultation and information provision exercises. Consideration of the US definition of the analytic-deliberative process in risk management terms (Stern and Fineberg, 1996; Presidential / Congressional Commission, 1997; Charnley, 2000) and also of the Royal Commission on Environmental Pollution's environmental policy decision process (RCEP, 1998) suggests that participatory risk assessment needs to be considered in terms of four stages: (i) the initial framing or definition of the issue or problem; (ii) the identification of data and information needs and how uncertainty will be managed; (iii) oversight of the assessment itself, and (iv) the evaluation of the risk estimates. There is a need to establish at which of these stages, and in what ways participation can be incorporated. The challenge is to develop *informed* processes that enable decisions involving science to be debated widely in a social context.

Broadly, current UK practice is that the public tend to become involved in the later stages of environmental decision processes, i.e. at the point of evaluating risk assessment output before the final decision is taken. Even then there may be limited opportunities for the public to influence the decision that is made on account of the inherent presumptions in the statute. Mechanisms for stakeholder involvement in risk decisions, while understood, have to-date not been adopted widely and still require evaluation in practice. Even at the international level, our review shows that experience is limited, although there are increasing attempts to apply participative processes to policy, plan and project-level decisions involving risk. These more participatory processes have been demonstrated to be effective in reaching decisions, although it would be naïve to assume that a more inclusive and deliberative process automatically results in lack of contention in relation to the decision. Indeed, involving the public may result in more diverse opinions as opposed to consensus.

As part of this research, we have developed criteria for effective participatory decision processes where risk is an important issue within the decision (Table 1; Homan *et al.,* 2001). These reflect broader criteria for effective public participation incorporating key principles of, clarity of objectives; representativeness; inclusivity; openness; deliberation; social learning and decision responsiveness. For environmental regulators, these are complex issues with far reaching policy, resourcing and practical consequences that require careful deliberation.

Table 1 Criteria for effective participatory decision processes involving risk

Clarity of objectives	• Are the objectives of the overall participation activity clear both to active and non-active participants, including the limitations of what can be achieved - i.e is the connection made between purpose, process and outcome?
Clarity of legal process	• Are the legal process and linked processes (e.g. planning) which will influence the decision made clear to all participants, including the limitations but also the responsibilities of these other processes?
Potential decision responsiveness	• Is the decision open to amendment if agreed to be appropriate by participants (i.e. the decision has not already been taken)?
Clarity of linked processes	• Are all participants provided with information about other linked participatory and information processes that have been, or will be, undertaken by other responsible authorities and by the Agency? • Is the process designed to integrate with rather than duplicate or conflict with any other participation activities organised by other authorities?
Consensus on agenda and procedures	• Is there sufficient opportunity for participants to have input to the agenda for discussion and decisions on the procedures to be used including the choice of facilitator/chairman/moderator? • If there is no opportunity for participant input prior to commencement of the process, are their opinions sought at the start? • Is there opportunity for participants to engage in the problem scoping – including agreement on the definition of the problem and the issues that will need to be addressed? • Is there opportunity for participants to discuss likely data and information deficiencies in the assessment process and to agree how these will be rectified?
Consensus on effectiveness	• Is there opportunity for participants to input their own views on what will make the participation process effective and for these criteria to be included in the evaluation?
Representativeness	• Are the participants in any participatory process representative of the full range of people and interests potentially affected? • Is the process of identification and selection of any specific participants objective and open? • Is opportunity provided for new or additional participants to take part in the process if identified by others and it is agreed that their participation would be beneficial?
Inclusivity	• Are the barriers to participation - physical, social, economic - removed or at least minimised as far as is possible? • Is the choice of location, times, venues, etc undertaken with due regard to local circumstances and participant preferences? • Is adequate notice given to participants of the dates and times of any event, and are their views sought on the latter as new events are arranged? • Are appropriate methods used to ensure that those who do not participate directly are made fully aware of the issue, the consultation being undertaken, where information can be obtained and a variety of appropriate opportunities provided by which they may make known their views if they wish to?
Transparency	• Is the participation process transparent and open from inception, through operation, to communication of its outcome? • Are the views, both for and against, of the majority and minority acknowledged in the outcome? • Are Agency staff and also officers in other authorities and in the applicant company, who are not directly involved made aware of the participation process?
Deliberation- General	• Are adequate opportunities provided for participants to engage in dialogue, discussion and group interaction? • Are adequate opportunities provided to everyone to put forward their personal opinion if they wish? • Is sufficient time allocated throughout the process to allow effective deliberation to take place and do participants feel that they have had sufficient time to take part to the extent that they want? • Is disagreement acknowledged and dealt with openly, but also managed to ensure that it does not impact adversely on discussion? • Does the process enable participants to improve their own anecdotal and intuitive knowledge by being exposed to relevant experiences (e.g. visits to sites, discussion with people who live close to similar facilities, etc)

Table 1 (cont'd) Criteria for effective participatory decision processes involving risk

Technical Deliberation	• Is information provided to ensure that all terms, definitions, technical details, are available to everyone in advance and are clear so enabling people to participate in discussion fully and critically? • Is a formal process involved which allows for the concerns and values of participants to be captured and recorded such that the criteria which will be relevant to the risk evaluation are agreed? • Is the technical assessment process sufficiently transparent and open to challenge and to input of alternative assumptions if agreed to be appropriate by participants? • Are adequate opportunities provided for the uncertainty inherent in factual information to be acknowledged, explained and discussed? • Are knowledge deficiencies openly acknowledged by the official contributors? • Are opportunities provided for expert knowledge and information to be challenged and claims to be tested through discussion? • Are opportunities provided for other expert knowledge agreed by participants to be relevant to the discussion to be made available to the process and to be considered directly – i.e. peer review? • Where questions cannot be answered immediately are adequate arrangements made to ensure that participants receive the information as soon as it is available? • Where it becomes apparent that information or knowledge is missing or insufficient are resources made available for further work or assessment to be undertaken?
Capability	• Are all technical experts, organisers and other officials providing input to the process sufficiently skilled as communicators and have received appropriate training? • Are all technical experts able to communicate and explain complex science and risk data? • Are all technical experts willing to be open about limitations in current knowledge? • Are sufficient financial resources allocated to the process? • Does the process have sufficient time allocated within the overall timetable to allow for any unforeseen issues and needs to be dealt with and responded to?
Social learning	• Does the process make a difference to participants in terms of their understanding of the issue and knowledge gained, in particular their understanding of the risk assessment process and its role in decisions? • Does the process lead to an improvement in the public availability of information? • Does the process promote understanding of different viewpoints? • Do people enjoy taking part?
Actual decision responsiveness	• Does the process add value to the decision? • Are recommendations which represent a consensus of participants' and respondents' views taken on-board in the decision? • If the process leads to challenge to existing Agency risk assessment methods and/or decision criteria is the Agency prepared to revisit these? • Is the decision communicated to all participants, non-participants and to Agency staff? • Is an evaluation (preferably independent) of the process completed and the results made known to participants and recorded for input to the design of future processes?
Enhancement of trust	• Does the process lead to an enhancement of the Agency's credibility as an environmental regulator and promote trust in its risk decisions?

3.2 Perspectives on participatory risk assessment

A key aspect of any decision-making process is to ascertain the role and degree of influence that stakeholders can realistically have. If there is little potential to influence a decision, then participation can create false hopes. In some cases it is clear that consultation, as opposed to participation, is required. It is important to establish, therefore, the risk decisions that can be made using more deliberative techniques. Whilst participation in risk assessment process is not new in itself (see Fischer, 1993), the focus of this study was to create the bridge between the calls for greater participation (RCEP, 1998; Green Alliance, 2000; House of Lords, 2000) and the practical context in which decisions on environmental risk are made.

Regulatory perspectives on participatory risk assessment

Seven extended telephone interviews were conducted with senior staff in the Environment Agency, including head office staff involved in public participation, team leaders for licensing, process industry regulation and enforcement, and area environmental planning staff. The primary objective of these interviews was to gain an initial understanding of internal views about participatory risk assessment. It was recognised that Agency experience to-date has been primarily of consultative processes related to regulatory responsibilities but some had been involved in broader stakeholder engagement processes.

Respondents had a positive view of public participation. Among the respondents interviewed, there was no reluctance to engage in the concept of broadening participation to open up risk assessments to public discussion and challenge. A number of beneficial potential outcomes were noted including:

- building of local knowledge into the risk assessment;
- the possibility of a more robust decision being taken which is less likely to be challenged;
- the provision of education about risk issues and risk behaviour;
- promotion of “social auditing”, and;
- the potential to increase trust in regulators and regulatory decisions.

The bulk of respondents’ experience was of traditional public participation activities including of public meetings relating to authorisation/licensing issues. Concerns were articulated about public meetings in being attended by people who are experienced in arguing cases and speaking, to the detriment of input by others. The current regulatory framework was seen as a potential barrier to participation, not least because the Agency is not always the sole regulator and there are often time constraints due to a statutory stipulation of response times (e.g. relating to permit applications). All of the respondents had either direct experience of risk assessment and/or understood the difficulties that the Agency has faced in communicating risk information. There was extensive discussion of the perceived technical barriers to participation and the difficulties that any regulator faces in presenting risk information in public.

The interviews suggested different, but not necessarily conflicting, views about the extent to which the public is interested in the technical aspects of risk assessments as opposed to what decision the Agency is going to make. Caution was expressed about generalising about public interests and skills with the view that there was a need to understand different potential audiences and also their potentially different roles in a participatory risk assessment process. As expected, health risks were identified as a difficult area for discussion as the Agency is not always able to deal with detailed and specific “scientific questions” about health impacts, often needing additional technical support.

Some noted that specialist Agency staff may not be necessarily confident about presenting technical issues in non-technical fora and that lack of confidence can impact negatively on public perceptions of Agency performance. There is a need to increase confidence in those who have to organise and/or take part in extended participation activities. This is partly about communication skills but also about increasing understanding about what more extended participation methods can achieve in practice

Stakeholder perspectives

Extended telephone interviews were conducted with 23 individuals, in the role of stakeholders:- twelve non-specialists and eleven ‘specialists’. Non-specialist interviewees were, on the whole, ‘members of the public’ who had had varying experiences of participation/ involvement in environmental decisions in the past. The specialist stakeholders included people in NGO/ pressure groups, local authorities and those representing industry. An initial interview, lasting approximately 10 minutes, was designed to generate background information about the participant’s prior experience of risk and participatory processes, and to engage them in the research. The participants were sent some brief reading material (a six-sided summary of some key information from the draft of the literature review) in order to provide them with background to the project prior to the longer, second interview, lasting about an hour.

In the pre-interviews, the discussion of trust and different sources of information produced familiar responses amongst the non-specialist stakeholders. People were asked to allocate a score of 1-5, where 1 is high trust and 5 is low trust. Government departments were ranked 3-5 (i.e. medium to low trust). NGOs were ranked 2 by everyone (i.e. medium to high trust). Industry was accorded the same rankings as government departments to a large extent but with a slightly larger score at 5. Academics received a spread of rankings depending on whether people considered that they were paid by government departments to provide advice, the majority of these being 2.

NGOs and pressure groups were regarded as important information sources by both specialists and non-specialists particularly for providing the ‘alternative viewpoint’ and raising the profile of an issue.

However, it was recognised that NGOs and pressure groups had the potential to be “emotional” and “single-minded”, although possibly more at a local rather than national level. The reliability of information from these groups was considered to therefore vary enormously. Most non-specialists had not used information from industry; most specialists had but had struggled to obtain it. Industry was perceived to have an important role as they have the fullest data sets and the best understanding of complex industrial processes.

Non-specialists perceived more barriers than specialists to wider involvement in the risk assessment process. Specialists felt that there was no avoiding science and technical issues and that people have to take these on board if they want to participate. In many ways the problem was not seen as being the scientific and technical language *per se* but the overtly jargonistic manner in which this can be expressed.

People were asked at what stage in risk decision-making they would like to be involved:

1. At the stage where the problem or issue is first being discussed
2. At the stage where you or your organization may be asked to identify the criteria/ key elements that will be used to help specify the risk
3. During the risk assessment process when technical experts are actually working on the data
4. When you will be asked to evaluate before a decision is taken.

Overall, the majority of respondents (specialist and non-specialist) wanted to have input at all stages of the risk assessment and decision process. Amongst non-specialists the least popular stage was during the risk assessment itself (Stage 3 above) although this was only a minority view. Most people felt that the regulator would gain the most relevant input at the outset of the process (problem definition) and/or at the end (decision-making). Arguably the public are involved only at stage 4 at the current time.

Seven criteria of effectiveness were explored: consensus on agenda; representativeness; inclusivity; opportunities for discussion; transparency; clarity of the linked decision processes; adequate time, and a decision which is responsive to the findings of the public participation. Most of the respondents felt that all of these criteria were very important. A number of people noted with regard to time that whilst this was very important it is also the case that decisions do eventually have to be made and cannot be indefinitely deferred. A number of specialists also felt that the notion of consensus should be approached with caution.

The interviews revealed a considerable enthusiasm for much earlier involvement in risk decision-making including, most importantly, in the framing of the problem but they also emphasised the importance of being able to affect the outcome.

3.3 Characterising decisions on risk

Regulatory decisions can appear as a homogenous set of unified processes, whilst in practice a wide range of different contexts for environmental decisions exist (Pollard, 2001), each with its own degree of flexibility and set of constraints (Table 2). In this research, a survey questionnaire established current practise of involving people in Environment Agency risk decision contexts and determined the respondents’ views over the potential scope for more involvement. Nineteen telephone questionnaires were conducted with a range of Environment Agency staff representing each of the decision ‘roles’ that the Agency has. Staff were interviewed from across the Environment Agency, based at head office (policy and science), at the region and at area level.

Detailed discussion of a number of different types of decision (Table 2), with the interviewees providing case studies, explored the background to the decision; the assessments involved; the nature of public involvement; the level of public interest; the information provided to the public; the response to this information, and whether consultation/participation was evaluated. The following represent the summary points to emerge from a detailed analysis of the interview transcripts:

- increasing levels of participation in risk assessment processes are taking place within the Agency;
- best practice examples of effective participation can be disseminated and learnt from;

- participatory processes need to be designed specifically to fit the local circumstances and the needs of the regulator and stakeholders;
- consistent and formalised approaches to participation can provide clear guidance and advice on communicating with, and involving stakeholders in risk decision processes;
- participation can be included into the role and remit of Agency staff involved in decision processes;
- third parties can sometimes represent the public interest; but there is a need for direct public involvement in many instances;
- stakeholders require information in a manner that can be understood in order to contribute informed feedback;
- in order to involve members of the public earlier in the decision process the supply of information will need to be brought forward.
- there is a need for increased information provision including that to provide greater understanding of risk decision-making and the role that the Agency and other bodies play within the process;
- regulators could have a role in directing the public to other information sources but this needs to be reviewed on a case-by-case basis;
- the evaluation of processes is required so that lessons can be learnt and best practice can be identified;
- the role that evaluation plays within decision processes needs to be agreed upon and a responsible person identified to ensure that it takes place;
- the only decision process where participation may have limited potential is that of the Agency as consultee;
- there appears to be greatest scope for participation where the Agency is acting as the regulator or is developing its own projects.

Table 2 Environment Agency roles and decision contexts

- *The Agency as regulatory policy developer* – where the Environment Agency drafts its own policies on how the statute should be implemented (regulatory policy development);
- *The Agency as developer* – where the Agency develops its own schemes through capital projects, for example, flood and coastal defence schemes and navigation works;
- *The Agency as project manager* – where the Agency assesses project risks in support of its own work or as a project partner in the works of others, for example for capital flood defence works, or site remediation under supplementary credit approval schemes where the Agency may act as the lead;
- *The Agency as discretionary consultee* – the Agency provides discretionary advice to other decision processes administered by other competent authorities, supported by risk assessments;
- *The Agency as statutory consultee* - the Agency provides statutory advice to other decision processes, again that may be supported by risk assessments requiring Agency review;
- *The Agency as regulator reviewing authorisations to operate* – the Agency reviews risk assessments sent to them as part of an application and uses these to inform decisions about authorisations and the attending licence conditions;
- *The Agency as regulator requiring improvement plans* – improvement plans are issued as part of the Agency's regulatory function and can often informed by prior risk assessments;
- *The Agency as independent assessor* – the Agency as a competent authority reserves a right to conduct its own independent risk assessment in cases where an operator's risk assessment is judged to be insufficient or where a second opinion is sought;
- *The Agency as partner* – partner to other Agencies/Authorities in general environmental improvements.
- *Agency as technical advisor to Government* – the Agency provides expert advice to Government as input to Government policy, for example, in advising on the state of the environment.

3.4 Simulating participatory risk assessment

A proposed participatory process was examined using a simulation exercise conducted in a 'workshop' format. The purpose of the workshop simulation was to open up the process of risk assessment to public involvement, particularly in the first stage of hazard identification. A single hypothetical case study was used, involving an application from a cement company for Agency authorisation to burn a proportion of tyre waste. This would normally require a modification to their existing authorisation that would be supported by a risk assessment. The objective was to test the potential for extending participation within the hypothetical risk decision, focusing particularly on the scoping/framing stage of the process, i.e. the hazard identification.

Workshop participants were engaged in a discussion format to simulate and demonstrate the effective engagement of the public in a risk assessment process. The process involved three stages:

- an initial 'scoping meeting' was held by the applicant, to scope out the issues surrounding the risk assessment and identify the questions which need to be addressed in the assessment;
- the second stage was an 'Update Meeting' held by the applicant to update the community on the progress of developing the application and to identify additional information and sources;
- the third and final stage was a 'Decision Response' meeting held by the Environment Agency where the decision on the application was reported back to the community.

The location of the workshop was identified by selecting a community which had gained recent experience of an Agency decision process, but not relating to the issue addressed in the simulation. This enabled the project to benefit from the previous experiences of the community, while not being sidetracked by the issue which they had been involved in. In total 17 people were recruited and attended the workshop process located in the Cheshire area (North West England).

The process of the simulation case study clearly demonstrated that the lay public can be, and wish to be, involved in the early stages of the risk decision process. As long as participants are offered background information to expand on the technical information provided, it is feasible for the lay community to be involved and to understand the issues and the process at an early stage in risk decision-making.

Time needs to be taken to communicate the proposals and the wider context of the application in advance. This offers an opportunity to build understanding of the need for the proposal and the associated issues. By doing this, participants are in a position to more effectively engage in discussions and dialogue around the issues and considerations relevant to the proposal/application.

The involvement of the community earlier suggests that the amount of questions arising throughout the process could be reduced as an understanding of the process and issues develops. Through earlier involvement – i.e. at the scoping stage - it appeared to be much easier for participants to move on to the next aspect of the decision process, once their questions and concerns had been responded to. Early involvement was felt to provide the opportunity for an earlier understanding of both the decision process and the issues, and allowed more time to be spent identifying questions and researching information. There were some issues raised relating to potential apathy and also about the complexity and quantity of the information that can deter people from being involved. Earlier involvement allows people to be brought along with the process and offers more time to assimilate and process information, enabling people to feel better prepared and more confident about their abilities to take part.

Information provision was a key area of concern, even within the case study process. The technical terminology associated with risk issues is not particularly conducive to public involvement. The group readily linked hazards and risks although not necessarily naming them 'hazard and risks'. They needed an introduction to the concepts of risk assessment to allow them to understand how the issues are addressed. However, the diversity of interests involved and the time available could not offer the opportunities (nor should it), for the community to become fully conversant with the 'technical terminology' associated with risk assessment. This should not affect the value of the feedback obtained but does mean that the process needs to be flexible enough to incorporate views from the community into the relevant parts of the risk assessment process. Issues that do not relate to the risk assessment *per se*, for example, relating to traffic, local amenity, visual impacts and to local economic impacts such as on house prices, must not be dismissed and people must feel that they are accepted as legitimate concerns. The public need to have a sense as to 'where' and 'how' these issues will be addressed.

Due to the level of emotion and concern which existed at the beginning of the meeting, the group worked best by being able to articulate their concerns in a constructive manner. The level of detail within an application to the Agency means that information provision must be staged to ensure that the whole group understands what is proposed, and feels confident that they know where they are in the process.

The workshop clearly showed that the public are interested in being involved in decision processes which could potentially affect them. However, the methodology by which they are involved is important. There are many different interests and levels of understanding within the community and it is the incorporation of all of these into a participatory process which is key to the successful involvement of the public within the decision. The community wanted to be a part of the decision process, but needed to know that there were other 'independent' experts involved who could also represent their interests. This involvement could take the form of written material to the community or having 'experts' present at the meeting to speak to the group and respond to questions. These and a number of other conclusions have been drawn from the simulation that are being considered within draft guidance.

4. Discussion and conclusions

The research has established the considerable potential for participatory risk assessment with support from Environment Agency staff, informed stakeholders and lay public who were involved in the simulation. The research offers the first step towards developing practical advice and guidance in support of DEFRA's and the Environment Agency's statements on stakeholder involvement issued in their joint "*Guidelines for Environmental Risk Assessment and Management"*. Through literature review, a programme of extensive stakeholder interviews and through a workshop simulation, this research has demonstrated the following requirements to be important:

- the integration of information provision, consultation and participation methods for all risk-based decision purposes if the key criteria of representativeness, inclusivity, potential decision responsiveness and enhancement of trust, are to be achieved;
- use of methods which optimise opportunities for deliberation and multi-criteria assessment must be included;
- a staged process which optimises stakeholder and public participation at key stages within the assessment process – i.e. problem definition and framing; assessment; evaluation;
- adaptation of methods and process to meet the different decision contexts and timescales over which regulatory assessments have to be conducted;
- achievement of a careful balance between consultation overload where multiple participation activities might be organised, - for example, by the Agency, the local authority and a developer/applicant, - and
- meaningful participation in the public's mind which will require evaluation of participation activities.

Disclaimer and acknowledgements

The views expressed in this paper do not represent Environment Agency policy and are those of the authors' alone. The authors gratefully acknowledge permission from the Agency to publish this work.

References

Apostolakis, G.E. and Pickett, S.E., *Risk Analysis*, 1998, 18(5): 621-634.

Assmuth, T.W. Toward value-based environmental clean-up – a trans-scientific venture. *Presented at ConSoil '98*, May 17-21, Edinburgh, 1998

Beck, U., *Risk Society*. *Towards a New Modernity.* Sage, 1992, London

Charnley, G., *Democratic Science: Enhancing the Role of Science in Stakeholder-based Risk Management Decision-Making*, 2000 http://www.riskworld.com

DETR, Environment Agency and Institute for Environment and Health *Guidelines for Environmental Risk Assessment and Management, Revised Departmental Guidance*, The Stationery Office, London, 2000

Fischer, F. In D. Smith (ed.) *Business and the Environment*, PCP, London, 1993, 98-115.

Green Alliance. *Steps into Uncertainty: Handling Risk and Scientific Uncertainty,* Green Alliance and ESRC Global Environmental Change Programme *2000*, 6pp. available at www.green-alliance.org.uk/Publications_

House of Lords Select Committee on Science and Technology, *Science and Society*, 3rd Report London: HMSO, 2000

Homan, J., Petts, J., Pollard, S.J.T. and Twigger-Ross, C. In: K.Anderson (ed.) *Proceedings VALDOR 2001 - The 2nd VALDOR Symposium Addressing Transparency in Risk Assessment and Decision-Making*, 10-14 June, Stockholm, Sweden, 2001, 398-406

Petts, J., *Land Contamination & Reclamation*, 1994, 2(4): 171-181

Petts, J., *Risk Analysis*, 2000, 20(6), 821-832

Pollard, S.J.T., *Risk, Decision, Policy*, 2001, 6: 33-46

Pollard, S.J.T., Fisher, J., Twigger-Ross, C. and Brookes, A. In: NATO/CCMS, Evaluation of Demonstrated and Emerging Technologies for the Treatment and Clean Up of Contaminated Land and Groundwater (Phase III), Special Session: Decision Support Tools, No.245, USEPA, Washington DC, EPA 542-R-01-002, 2001, 105-116

Presidential/ Congressional Commission on Risk Assessment and Risk Management *Framework for Environmental Health Risk Management*, Final Report, Volume 1, 1997

Royal Commission on Environmental Pollution (1998) *Setting Environmental Standards*. 21st report. London: HMSO

SNIFFER. *Communicating Understanding of Contaminated Land Risks*, Report SR97(11)F, Scotland and Northern Ireland Forum for Environmental Research, Edinburgh, Scotland, 1999, 30pp.

Stern, P.C. & Fineberg, H.V. (eds) (1996) Understanding Risk: Informing Decisions in a Democractic Society. Washington DC: National Academy Press

D.3 Lecture Session:

Decision support
in complex cases

HUMAN HEALTH AND OTHER RISK DRIVERS TO PRIORITIZE SITE REMEDIATION

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ABSTRACT: **Remedial actions at soil and groundwater cleanup sites have traditionally been addressed on an individual, case-by-case basis, as needed to address regulatory requirements. However, effective management of large portfolios of remediation sites (such as hundreds or thousands of UST sites owned by a single company) requires coordination and prioritization of individual site response actions to optimize the degree of risk reduction achieved with available resources. To meet these management objectives, two new risk-based management tools have been developed and implemented by the authors: i) a simple risk-based classification system, that can be employed to prioritize response actions, identify key risk drivers, and measure risk reduction progress over time for the full site portfolio; and ii) a lifecycle cost management system that can be employed to forecast remediation spending and optimize risk reduction benefits. For use in prioritizing response actions at remediation sites, "risk" is defined as the negative consequence of no action. In this context, sites may be classified in terms of key risk drivers, including both potential health and environmental impacts (primary risk drivers), as well as regulatory, community, off-site property, and transactional concerns (secondary risk drivers). Individual site classifications, based on the Class 1 through 4 designation presented in the ASTM RBCA Standard, can be compiled to establish a risk distribution for the full remediation site portfolio. These data are then be used to identify near-term, high-risk sites; define the key risk drivers for the portfolio; and, by periodically repeating the classification survey, track the progress of remediation efforts in reducing total portfolio risk over time. This risk-based site prioritization system has been applied to a portfolio of over 1500 petroleum release sites in the U.S. Results of this study show that about 70% of these sites pose no threat of impact on human or ecological receptors in the near-term (i.e., 2 years). Rather, remediation decisions at these sites were driven by secondary risk drivers (i.e., regulatory requirements or transactional issues), which do not represent health or environmental protection imperatives. In addition lifecycle cost projections were compiled for this same site population and used to identify regional variations in average remediation costs attributable to differences in management approach or regulatory requirements. The cost data can be combined with the risk classification data to identify cost control opportunities at sites where secondary risk factors are driving the site remediation.**

INTRODUCTION

Traditionally, environmental remediation sites have been managed individually with the goal to achieve regulatory compliance. However, for corporations and government organizations responsible for the management of large portfolios of remediation sites, management of sites individually is not cost effective and does a poor job of controlling portfolio risks. Effective management of remediation portfolios requires i) establishment of a single *risk management standard* which is applied in to each remediation site, ii) measurement of progress in achieving this risk management standard, and iii) adjustment of resource allocation and project management to ensure compliance with the risk management standard at each site.

Risk Management Standard. Under a *multi-site management strategy*, risks associated with multiple remediation sites are assessed, prioritized, and managed in a cost-effective manner. A single *risk management standard* is applied to all remediation sites in the portfolio. This risk management standard must address all aspects of risk associated with the site:

- ***Health/Environmental Care***: Protect human health and the environment.
- ***Effective Resource Allocation***: Utilize resources effectively to assess, prioritize, and manage risk.
- ***Regulatory Compliance***: Manage compliance with applicable environmental laws and regulations.

At each remediation site, site assessment and response actions must be implemented in the timeframe necessary to prevent unsafe health/environmental exposures (primary risk drivers) and address associated community/business concerns (secondary risk drivers). Remedial measures are prioritized at sites posing a current or imminent exposure problem, and resources allocated so as to maximize the overall risk reduction of the remediation site portfolio over time. Under this approach, engineered remedies are targeted toward time-sensitive conditions and/or risks posed to actual, existing receptors. In the absence of these conditions, natural attenuation may be employed to reduce risk of potential future exposures. Appropriate response actions for each remediation site are determined on a site-specific basis, as needed to address both primary and secondary drivers.

Measuring Progress: Classification of Key Risk Drivers. Prioritizing sites and allocating resources efficiently is the greatest challenge in management of a large remediation portfolio. We have developed a simple site classification system which facilitates the collection and analysis of the data required to make these program management decisions. This tool allows identification of health/environmental exposures and associated community/business concerns and provides a means to measure progress in addressing these risks.

Under government environmental regulations, the term *risk* is typically a measure of the hazards posed to human health and the environment. Such health or environmental hazards represent the primary concern at each remediation site. However, for use in strategic planning of remedial actions at numerous sites, a broader, multi-attribute characterization of risk is required to distinguish between sites of equivalent human health or environmental concern. To prioritize remediation sites, risk is defined as the potential *negative consequences of no action*, where *consequences* relate to the immediacy and magnitude of potential impacts. Potential impacts or *risk drivers* include both *primary* factors, i.e., potential of human or environmental exposures in excess of safe levels, and *secondary* factors related to community, regulatory, or business concerns. To effectively manage risk for a portfolio of sites, this full range of risk drivers must be assessed for each remediation site, and response actions prioritized to address near-term, higher-risk conditions.

Figure 1 presents a site classification system designed to characterize both primary and secondary risk drivers for remediation sites on a site-specific basis. For use in prioritizing response actions among a large population of remediation sites, the system classifies each risk driver in a manner consistent with the ASTM RBCA process based on the *time to impact,* as follows:

- Class 1: Immediate impact or concern
- Class 2: Near-term impact or concern (within 2 years)
- Class 3: Potential future impact or concern (within 2 to 10 years)
- Class 4: No anticipated impact or concern

As indicated on Figure 1, each site is classified by a two-digit classification code related to the overall Primary Factor rating and overall Secondary Factor rating (e.g., 2/1 for a site with a Class 2 health/ environmental rating and a Class 1 secondary factor rating). This classification communicates the type and relative urgency of the response action required for each site. High-priority health/environmental ratings (i.e., Class 1) require the most immediate response. However, for sites which pose no near-term health/environmental concern (i.e., Class 3 or 4), near-term secondary factors (e.g., Class 1 for community, regulatory, third-party, or transactional issues) may serve as the principal drivers in prioritizing response actions. In addition, the letter codes of the controlling drivers for the primary and secondary ratings may be reported in order to communicate the specific cause of the site classification (e.g., 2G/1T indicates a health/environmental Class 2 rating due to groundwater and a secondary Class 1 rating due to transactional concerns; see Figure 1).

This simple classification system can be used to prioritize sites for remedial action and to measure progress in achieving the risk management standard.

Prioritize remedial actions: Class 1 represents a potential existing impact, and all Class 1 sites must be addressed immediately. Class 2 sites should be addresses promptly to prevent or mitigate the expected near-term impact. Class 3 and 4 sites can be addressed as needed based on available resources.

Identify the types of actions required: The letter code identifies the specific risk driver controlling the site classification. Remedial action should be targeted to address this risk driver.

Primary Risk Drivers: Health/Environmental Impairment		Site Class	Letter Code
Groundwater	Affected GW impacts on drinking water well or discharge to surface water resource or sensitive ecological habitat.	*1-4*	*G*
Soil Exposure	Affected soil with potential for exposure to public, livestock, or wildlife; leachate release to GW; or runoff to surface water.	*1-4*	*S*
Vapor Impacts	Vapor accumulation at harmful level in building, utility, or other enclosed space.	*1-4*	*V*
Non-Aqueous *Phase Liquids (NAPL)*	NAPL impact on drinking water well, utilities, surface water, or sensitive habitat.	*1-4*	*N*
	OVERALL HEALTH / ENVIRONMENTAL RATING	***Lowest value above***	***Controlling Driver Code***
Secondary Risk Drivers: Community/Regulatory Issues		Site Class	Letter Code
Community Issues	Community concern regarding property remediation and development.	*1-4*	*C*
Third-Party/ Off-Site Impacts	Impairment of non-owned, non-leased, or third-party property.	*1-4*	*O*
Regulatory Factors	Enforcement action for non-compliant conditions.	*1-4*	*R*
Transactional Issues	Impairment of pending sale or lease action or expiration of reimbursement source.	*1-4*	*T*
	OVERALL SECONDARY RATING	**Lowest value above**	**Controlling Driver Code**

Note:

1) Site Classification rating for Primary and Secondary Drivers indicates relative urgency for remedial response action, as follows:

- Class 1: Immediate impact or concern.
- Class 2: Near-term impact or concern (within 2 years)
- Class 3: Potential future impact or concern (within 2 to 10 years)
- Class 4: No anticipated impact or concern

2) Site Classification consists of two digits corresponding to lowest Primary/Secondary ratings among relevant risk drivers (e.g., 2/3). Risk drivers controlling Primary and Secondary Factor ratings can be indicated by letter code (e.g., 2G/ 3C).

Figure 1. Key Risk Drivers and Site Classification System

Measure progress in risk reduction: By periodically updating the risk classifications and comparing the current classification to prior results, risk reduction can be measured quantitatively. A total portfolio risk score can be calculated as follows:

$$\text{Total Risk Score} = \sum_{\text{All Sites}} (\text{5-Site Classification})$$

Using this equation, a larger total risk score equates to more risk in the portfolio of sites. A reduction in total risk score, a shift is risk distribution from high risk sites to low risk sites, or an increase in sites removed from the portfolio through case closure all represent progress in achieving the *risk management standard*. Risk reduction can be tracked for an entire portfolio, by regional manager, or by regional consulting company.

Identify key risk drivers: The contribution of individual risk drivers to total portfolio risk can be measured by calculating the reduction in total portfolio risk in the absence of the specific risk driver (assuming that all risk due to the risk driver has been addressed). An importance factor can be calculated as follows:

$$\text{Importance Factor} = \frac{\text{Reduction in Portfolio Risk Score}}{\text{Number of Sites}} \; x \; 100$$

Based on this analysis, program level initiatives can be developed to address the key risk drivers across the portfolio of sites.

Allocating Resources: Lifecycle Cost. In addition to identifying and managing risks across remediation sites, identifying and controlling expected costs is a key to effective multi-site management. By linking estimated remediation costs to the identified risk drivers, opportunities to reduce costs can be identified while ensuring the protection of human health and the environment.

The *risk management benchmark* represents the project scope and associated cost necessary to achieve the *risk management standard* at an individual site. Following completion of the site assessment, the benchmark scope may be forecast based on the probable actions needed to protect public health and the environment and achieve regulatory case closure. For each task, associated costs may be calculated based on estimated task quantities, duration, and standard unit rates or approximated based on prior experience on similar projects. The risk management benchmark scope must be designed to address all *risk drivers* present at the sites, as identified under the risk-based site classification system (see Figure 1).

The *health/environmental protection* scope represents a remedial action strategy targeted toward *primary risk drivers* only (see Figure 1). Following completion of the site assessment, the health/environmental protection scope can be defined as the specific measures needed to prevent exposure of human or ecological receptors to harmful levels of site constituents via affected soil, groundwater, vapors, or non-aqueous phase liquids. For a given site, this *exposure control strategy* may differ significantly from the risk management benchmark scope, in that remedial actions are targeted solely toward health and environmental protection, without regard for secondary risk drivers such as regulatory or business concerns.

Because the *health/environmental* scope addresses only primary risk drivers while the *risk management benchmark* scope address all risk drivers, the *health/environmental* cost will always be less than or equal to the *benchmark* cost. In order to identify cost control opportunities, the difference in costs can be assigned to specific secondary risk drivers. In general, the cost allocation to each secondary risk driver should be consistent with its risk-based site classification rating (e.g., Class 1 = immediate high concern, Class 4 = no anticipated concern). For example, if the site has been classified with a Class 1 transactional risk driver (1T), then the cost difference between the risk management benchmark scope and the health/environmental protection scope will likely be strongly influenced by the transactional driver.
The lifecycle cost tool can be used to ensure the efficient allocation of resources across the portfolio of remediation sites:

Forecast Required Resources: Quantify the expected cost to achieve remedial goals throughout the portfolio. When limited resources are available, expenditures at sites with no near-term impacts may be deferred.

Identify cost control opportunities: Identify sites where costs are being driven by secondary risk drivers. Develop more cost effective approaches to address these risk drivers.

Compare remediation cost across the portfolio: Identify difference in remediation cost by region or consultant. Promote the use of more cost effective remediation technologies to manage these cost differences.

Risk Management Process Steps. Under an effective risk management system, risk-based decision-making procedures are applied on a site-specific basis to address emergencies, characterize site conditions, define further risk reduction needs, and select and implement cost-effective remedial measures. This individual site evaluation generates key management data that support the *program* management effort. These new risk-based site classification and lifecycle cost tools facilitate the collection and analysis of this data. When compiled on a periodic basis, summary information regarding the current site classification, remediation cost projection, and remedy/closure schedule can be used to inventory high-priority sites (e.g., Class 1 ratings), quantify overall risk reduction (e.g., lower site classifications, increased case closures, etc.), and track the benefit of past expenditures. On this basis, program directives regarding individual site response schedules can be designed for optimal risk reduction.

CASE STUDY APPLICATION

Our *multi-site management system* has been applied to a portfolio of over 1500 petroleum release sites located across the country.

Site Classification. For each site, the risk classification was established using a *risk classification worksheet* consisting of three to five yes/no questions for each primary and secondary risk driver. The *risk classification worksheets* were completed by the local consultants for each site. To provide a conservative assessment of unknown conditions, these conditions were given the same risk ranking as for sites where the adverse condition was known to exist. The risk worksheets were completed on Excel spreadsheets, facilitating the compilation of results into a database.

Lifecycle cost estimates were also provided by the local consultants. Risk management benchmark costs were estimated to address all risk drivers associated with the site and health/environmental protection costs were estimated to address only primary (health/environmental) risk drivers. Again, the data were provided on Excel spreadsheets.

Data Analysis. Data provided by local consultants were complied into an Access database. Each site was reviewed to ensure data accuracy and internal consistency. To facilitate analysis of the data by regional program managers, specific queries were provided in a user-friendly interface. Programmed queries allow for analysis of i) Site Prioritization: sites ranked by type of impact and urgency of response action, ii) Risk Reduction Progress: change in total risk score for a portfolio of sites from one analysis period to the next, iii) Key Risk Drivers: contribution of individual risk driver to total portfolio risk across sites, iv) Cost Control Opportunity: opportunity to reduce total portfolio remediation costs through the use of more cost effective methods to address secondary (non-heath) risk drivers.

RESULTS AND DISCUSSION

Risk classification data were collected for 1,562 petroleum release sites located throughout the United States. As shown in Figure 2, 68% of these sites had a health/environmental classification of 3 or 4, indicating no near-term impacts at these sites. In contrast, 63% of the sites has a secondary classification of 1 or 2, indicating on-going or near-term regulatory or business impacts. These results indicate that the majority response actions for petroleum release sites in this portfolio are driven by regulatory or business issues and not by health or environmental impacts. In order to track risk reduction over time, a total portfolio risk score was calculated as described above. The portfolio of 1562 sites had a primary factor risk score of 3270 and a secondary factor risk score of 4346.

An importance factor for each primary and secondary risk driver was calculated as shown previously, by calculating the normalized reduction in total risk score if the individual risk driver was completely eliminated for the risk classification process. Results of this importance factor analysis are shown in Figure 3. The groundwater and vapor pathways were the most important contributors to total health/environmental risk with importance scores of 19 each. Third-party impacts were the most important contributor to secondary risk drivers with an importance score of 63. This analysis indicated that a portfolio wide initiative to address third-party impacts associated with the release sites would result in the greatest reduction in total portfolio risk.

In addition to risk classifications, risk management benchmark lifecycle cost data were collected for 1,634 petroleum release sites. At each site, costs were reported to address all identified risk drivers and achieve regulatory closure. In addition, separate costs were reported to address only health/environmental risk drivers. Costs required to address secondary risk drivers (after health/environmental drivers have been addressed) were 38% of total estimated remediation costs. This analysis indicates that developing more cost effective approaches to address business and regulatory concerns can yield significant cost savings without compromising protection of human health and the environment.

The site classification and lifecycle cost data collected for this portfolio of petroleum release site have been used to prioritize remediation and allocate resources.. High risk sites have been targeted for immediate action and low risk sites have been targeted for closure. Both risk classification and lifecycle cost data are being updated semi-annually to reflect progress in achieving the *risk management standard.* A preliminary analysis of follow-up risk classification data indicates that a greater than 10% reduction in total portfolio risk has been achieved in a one year period indicating that this *multi-site management strategy* is successful in bringing sites to the risk management standard.

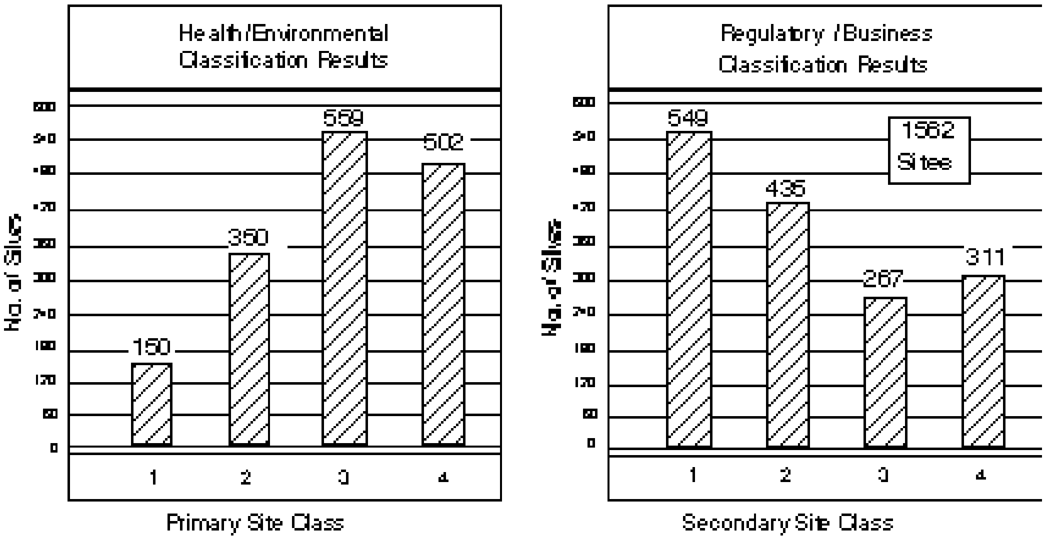

Figure 2. Risk Classification Results for 1,562 Petroleum Release Sites

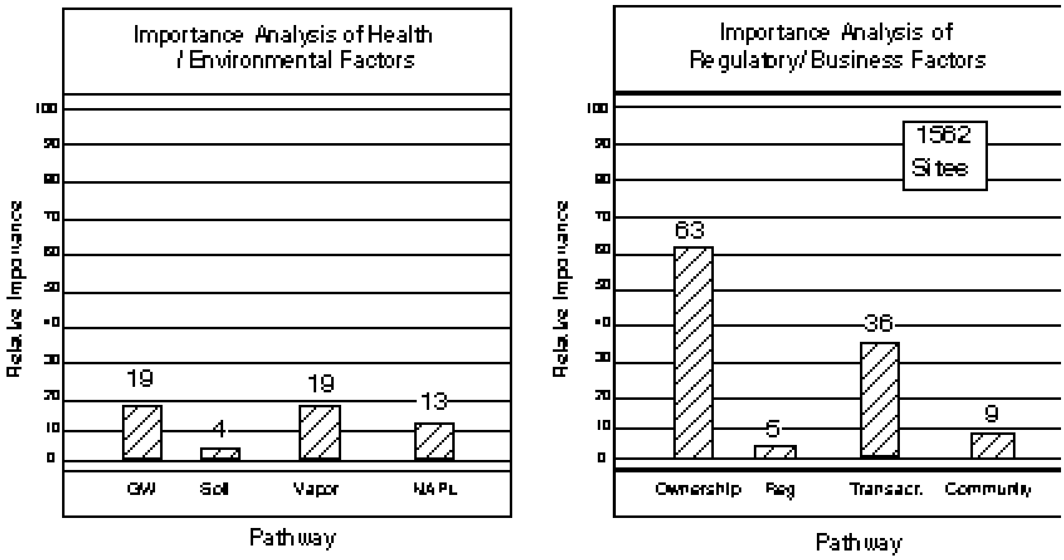

Figure 3. Importance Factor Analysis for 1,562 Petroleum Release Sites

DESYRE – DECISION SUPPORT SYSTEM FOR REHABILITATION OF CONTAMINATED SITES

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1. INTRODUCTION

Remediation of contaminated land has become a severe matter of concern for its economic, environmental and social relapses.

Making decisions about remediation means to play with several technical options, to face risk with a time perspective, to define an economic plan, to outline the future social and economic development of the territory. This process involves many experts and stakeholders, thus, decision making has to consider uncertainty and different interests.

The terms of the decision making problem became particularly hard for mega-sites. In these cases, the extension and heterogeneity of the site contamination (hundreds or thousands hectares), the socio-economical implications with the site rehabilitation, the overall costs for the remediation, the presence of multiple stakeholders, the economical, technical and environmental unfeasibility of local interventions and the need for integrated sustainable solutions, make the nature and volume of information extremely difficult to manage. The remediation of megasite requires firstly a planning phase, defining suitable objectives and sustainable scenarios, and, secondly, a further analysis of risk and technological options for the definition of specific interventions at a local level.

A system to make manageable by decision makers available data and expert judgements about environmental, socio-economical and technological issues is required. A decision support system is expected to provide coherent and realistic scenarios through the link of all the issues involved and the management of the possible intervention options. The decision flow must be transparent and reproducible.

For contaminated sites remediation, several attempts have been made to codify specialist expertises into decision support tools (Bardos et al., 2001). In recent years, considerable interest was focused to use Geographic Information Systems (GIS) as a decision support system (Eastman et al., 1993). GIS can elaborate several basic spatial information (e.g., spatial distribution of contaminants into different environmental media, dislocation of the different remediation technologies, etc.) but it does not provide alternative solutions with a proper decision flow. Integrating Decision Science's tools into GIS software appears highly stimulating. However, exploration into this area (Eastman et al., 1993) indicated that tools available for this type of analysis were remarkably poor.

In order to provide a decision support tool for the remediation of contaminated mega-site, encompassing the planning and the intervention project phase, the software DESYRE (DEcision Support sYstem for the REqualification of contaminated sites) has been developed.

The DESYRE Specific main objective is the creation and comparison of different remediation scenarios in terms of residual risk, technological choices and socio-economical benefits.

The software users are supposed to be a multi-disciplinary team of experts, involving risk assessors, socio-economists and technology engineers. DESYRE provides support to the experts along several steps for contaminated sites rehabilitation, encompassing characterisation, socio-economic evaluation, risk assessment and technologies ranking. It allows the integration, spatial evaluation and analysis of available information by using GIS functions and a number of decision support tools implemented in the system. Finally, the DESYRE final output is addressed to decision makers for comparing benefits, costs and impacts of different strategies and technical solutions.

An overview of the DESYRE DSS is following presented, while a detailed description of the system is in preparation to be submitted for publication to a peer reviewed international journal.

2. DESYRE STRUCTURE

DESYRE is structured into five modules integrated into a GIS framework (Figure 1): four analytical modules, Socio-economical, Characterisation, Risk assessment and Technological, and a Decision module. The four analytical modules are supposed to be used by the multi-disciplinary expert team, while the decision module is addressed to stakeholders such as public decision makers, planners, site owners, investors and associations.

The socio-economic module addresses the socio-economical constraints generated by different land uses. The resulting scenarios are defined and ranked with Fuzzy Logic Analysis. The module allow the experts to select the most attractive, from a socio-economical point of view, land uses to be considered in risk assessment. In fact, sensitive receptors and remediation objectives depends on the selected land use. In practice, residential uses, for instance, require more restrictive remediation objectives than industrial uses. Specific contents and details of this module are reported in another contribution presented in this conference (Mannino et al.).

The site characterization module supports the analysis of contaminant spatial distributions and provides as much of the data necessary to run fate and transport and risk assessment models. The spatial distribution of contaminants are analysed by using geostatistical methods, including variography and Kriging. Variography is used to quantify and model the spatial correlation between sample locations. Kriging is used to map contaminant distributions based on observed values and their spatial relationships, as inferred from the variography. Contaminants in surface, subsurface soil and groundwater are considered.

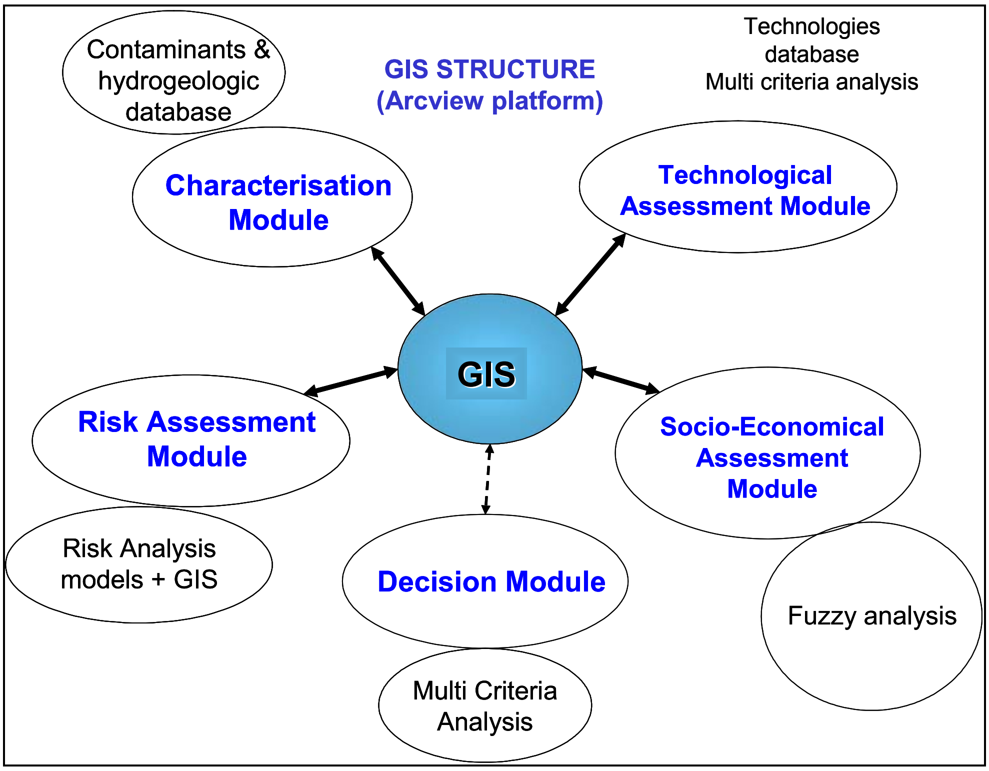

Figure 1. Modular structure of the DESYRE DSS. All modules are integrated in a GIS environment.

The risk assessment module provides tools for human and environmental risk analysis of contaminants in soil and groundwater. Risk calculation is based on standard algorithms, (US-EPA, 1989; RBCA-ASTM, 1998), while a novel procedure has been developed to investigate the spatial distribution of risk. Moreover, the final risk estimation is intended to be used for the selection of remediation technologies. For this purpose, chemicals are gathered into six classes according to the classification of technologies treating capability. Considered exposure pathways are the ingestion and dermal contact with soil, the inhalation of vapour and particulate emissions, groundwater ingestion and flow into surface water. Considered receptors are humans, groundwater and surface water. Databases for contaminant physicochemical and toxicological properties are included.

A site zoning is performed according to contamination distribution and risk levels. Risk analysis is applied twice: in a pre-remediation phase, to provide a site zoning according to risk levels, and in a post-remediation phase, to evaluate the residual risk after the application of a technological set. In the pre-remediation phase, the risk analysis is applied for an homogeneous area to every contaminant class. It provides maps of risk based on actual contamination. All maps point out the areas with a non acceptable risk for human health which need a mitigation intervention. After the technological module is applied, the post remediation risk analysis produces residual risk maps. Areas where safety measures are needed for a further mitigation of residual risk to acceptable levels are outlined.

The technological module is developed into a stepwise structure. Firstly the application of a set of criteria and a wide database support the selection of a subgroup of suitable technologies for the specific site. A number of parameters, among which performances, actions on contaminants, geological and hydro-geological requirments and commercial availabilities, are considered. Secondly, based on the selected pool, remediation technologies are indicated for the mitigation of actual risk. It is performed on the pre-remediation risk map for each contaminant class. More than one options are usually assigned for the same area. A ranking system for the selected technologies is applied: a score to each technology is calculated for each technology on the basis if key criteria, among which cost, development time, efficiency (or performance), reliability, public acceptability. For this purpose, multi-criteria decision analysis (MCDA) methods, such as a modified Analytic Hierarchic Process (AHP), (Ramanathan et al., 1994, van Den Honert et al. 1996 and Critto et al., 2002), are applied. Based on the technologies ranking and actual risk, the expert defines alternative technological sets, i.e. combinations of technologies extended spatially and temporally. For each set, a simulation of the interventions performances produces residual risk maps.

The Decision module provides the description of alternative remediation scenarios. A scenario is an inclusive and suitable solution for the rehabilitation of a contaminated site, including the technology set, the associated human health and environmental feedback, in terms of residual risk, and the socio-economic benefits of the site rehabilitation for the specific use. Technological, environmental and socio-economical aspects are described by macro-indexes that are derived directly from the technological, risk assessment and socio-economical modules, respectively. Multi Criteria Analysis (MCDA) methodologies are applied to define indexes based on criteria and rules. A scoring system is provided for the stakeholders to rank alternative scenarios according to their major sensitivities, e.g. to environmental benefits, or costs, or time etceteras.

A scheme of the information flow through the DSS is represented in figure 2.

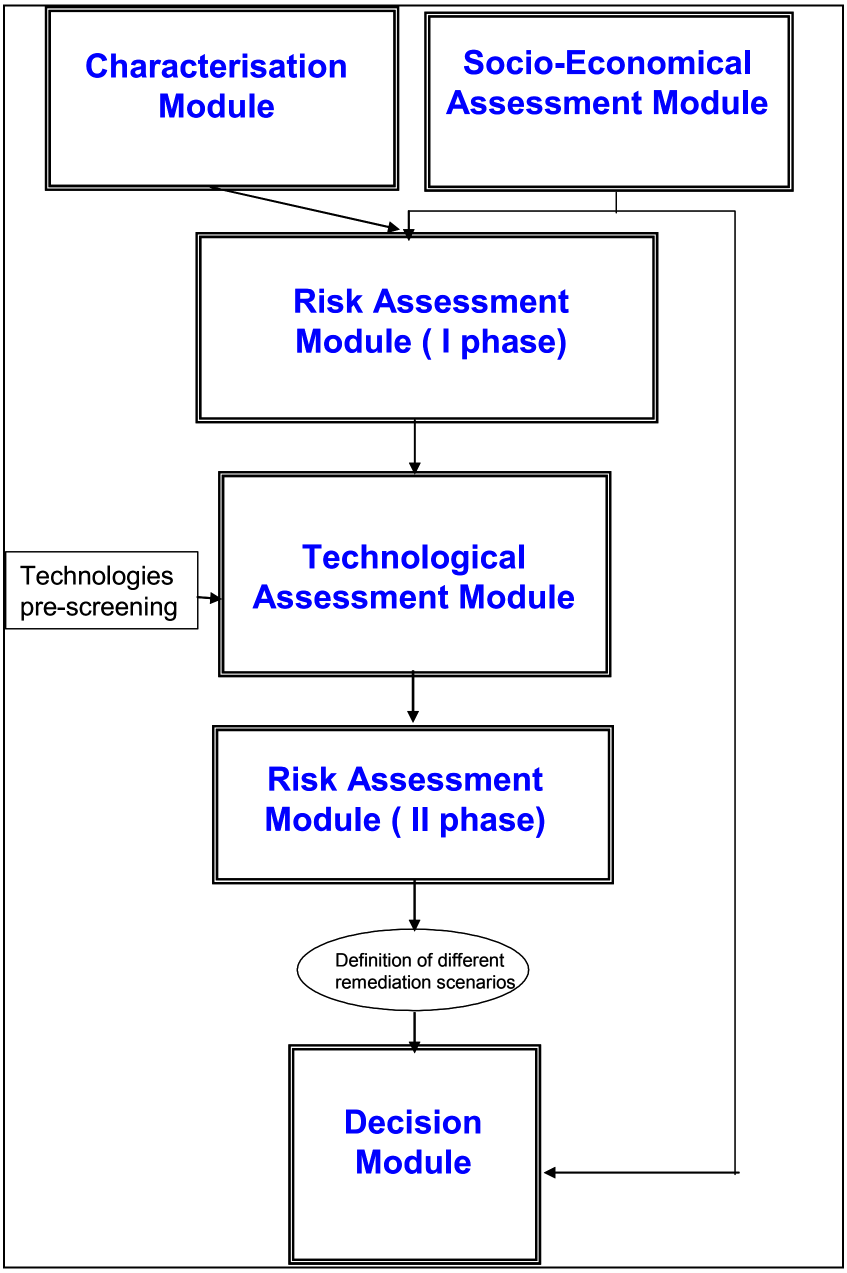

Figure 2. The DESYRE DSS information flow.

3. THE DESYRE SOFTWARE

A DESYRE prototype software has already implemented. It is based on a GIS software (ArcView 8 for Windows) and supported by Visual Basic to develop the different applications. A friendly inter-face makes DESYRE an easy tool also for not GIS-trained users. A clear guideline makes the decision flow transparent and reproducible, by ensuring that the process itself is documented (i.e. all parameters, assumption, and data used to reach the decision should are clearly schematized).

DESYRE has been tested by using the mega-site of Porto Marghera, Venice, as case study. Porto Marghera is c.a. 3600 ha industrial zone, with c.a. 500 ha accounted for surface water. Most common contaminants are: PAHs, amines, dioxins, halogenated organic compounds and metals (As, Hg, Cd, Pb, Zn, etc.). In 1998 an agreement among local authorities and a panel of industries located in the site was signed to support a sustainable management of the land. Furthermore, according to the national law (426/1998) Porto Marghera was included in the set of contaminated sites of national interest.

The DESYRE modules of socio-economy, characterisation, risk analysis and technology assessment were so far successfully applied, and alternative scenarios have been developed. An optimization of the software functions has been also performed based on experts evaluations reported in the case study exercise. The case study proved the high potential of DESYRE to be applied for planning remediation scenarios of megasites. Moreover, DESYRE gives the support for a participatory approach of multiple stakeholders, thus leading to the consensus on sustainable solutions.

4. CONCLUSIONS

The strengths and peculiarities of DESYRE are: (a) it requires an active role of the expert in order to avoid any simplification; (b) it allows an integrated analysis of economical, socio-economical, technological and environmental issues; (c) it allows a GIS based spatial analysis for planning purposes, e.g. zoning and prioritization; (d) Multi Criteria Analysis methodologies allows a transparent decision process.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

ASTM-American Society for Testing and Materials, Standard Provisional Guide for Risk-Based Corrective Action, Final report, PS 104-98, ASTM, Philadelphia, 1998.

Bardos, R.P., Mariotti, C., Marot, F., Sullivan, T., Framework for Decision Support used in Contaminated Land Management in Europe and North America, *Land Contaminated & Reclamation, 9,* 149-163, 2001.

Eastman, J.R., Kyem, P.A.K., Toledano, J., Jin, W., *GIS and Decision Making, UNITAR Explorations in GIS Technology - Vol.4*, United Nations Institute for Training and Research, Geneva, 1993.

Ramanathan, R., Ganesh, L.S., Group preference aggregation methods employed in AHP: an evaluation and an intrinsic process for deriving members's weightages, *European Journal of Operational Research*, 79, 249-265, 1994.

US-EPA, Risk assessment guidance for superfund Vol 1, Human health evaluation manual, Final Report, EPA/540//1-89/002, Washington DC, 1989.

Van Den Honert, R.C., Lootsma F.A., Group preference aggregation in the multiplicative AHP. The model of the group decision process and Pareto optimality, *European Journal of Operational Research*, 96, 363-370, 1996.

ABC-TOOL: ASSESSMENT OF BENEFITS AND COSTS FOR INDUSTRIAL CONTAMINATED SITES

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Owners of industrial sites are often facing a legacy of past site management and, at the same time, an increased concern of society for a healthy environment. In Europe these industrial sites are often operational for a long time and unravelling their history is not always easy. Moreover, they have to deal with a combination of multiple contaminants in a complex sub-surface. This confronts site owners with a difficult task to combine high standards and at the same time run a competitive company. In general site investigation and remediation of these sites is highly complicated and costly. To obtain more insight on options in remediation techniques and their effect in time and on load, merit and costs, the ABC tool has been developed. In this ABC tool the European fragmented knowledge and experience is brought under one system that gives a fast impression of the site possibilities and improves in time when more information is brought in. ABC is developed under the European Union project PURE. This paper describes the PURE project, the function and use of the ABC-tool and the suitability of the ABC tool within a site characterization process.

PURE PROJECT

Introduction

The pollution of industrial sites is a major problem in many industrial regions throughout Europe and worldwide. These contaminated sites pose a serious risk to the population and to the environment, either through direct contact with contaminated soil or by the impact the contaminated soil has on the groundwater. This concern for water resources protection versus pollution from contaminated site and the awareness of the need for improving the contaminated land management were the drivers for the industry, as 'problem owners', to initiate the PURE project through the NICOLE network.

PURE is the acronym for Protection of Groundwater Resources at Industrially Contaminated Sites. The European Commission supports this three-year project since April 2000 under the Fifth Framework Programme in Thematic Programme:
The project started in April 2000 and will be completed in April 2003
Program: Energy, Environment Sustainable Development (EESD),
Key Action: Sustainable management and quality of water; Abatement of water pollution from contaminated land, landfills and sediments.
The contribution of the European Commission is 2,9 million Euro.

Short description of the project

PURE is aimed at the prevention of contamination of groundwater from industrial sites by priority pollutants such as recalcitrant Chloroorganics, BTEX and heavy metals; the innovative results obtained in the project will be of a wide applicability being validated on three different industrial sites. The PURE project is divided in two main parts the Assessment part and the Implementation part. Each of the parts is divided in sub-projects. The expected results are:
A tool for risk assessment (report)
A code improvement and decision support system (software)
Know-how of technologies for organic contaminant remediation and stabilisation of metals below regulated concentrations, both in soil and water matrices (technology).
The consortium comprises 5 universities, 2 research centres, 2 service and 4 industrial partners (table 1). TNO is scientific coordinator of the consortium.

Table 1- PURE consortium

EniChem SpA (Industry/site owner) EniTecnology (Corporate research centre) Aquater (Service provider)	Italy	University of Konstanz (University) University of Stuttgart (VEGAS) (University) FORD (Industry/site owner) ICI Paints (Industry/site owner)	Germany
TNO (Research centre) AKZO-Nobel (Industry/site owner)	The Netherlands		
EAWAG (University)	Switzerland	University of Cranfield (University) VHE (Service provider)	United Kingdom
Yeditepe University (University)	Turkey		

Innovation

The different gaps in knowledge are tackled that cause stagnation of the remediation of heavily contaminated sites. These gaps essentially can be allocated to ineffective methods for site characterisation and incompleteness of process knowledge and expertise to tackle pollution problems at industrial sites.

Project set up

The project has been set up in two main parts: SICHAMORE and TREES.
The one, SICHAMORE, SIte CHAracterisation and MOdelling for REmediation (Sichamore), comprises work packages 1, 2 and 3 is focussed on the initial site characterisation of contaminated industrial sites, while the other, TREES, Techniques for Earnest Environmental contaminants in Soil and groundwater, comprising the work packages 4, 5, 6, 7 and 8, is focussed on new techniques for the actual remediation of such contaminated sites (figure 1).

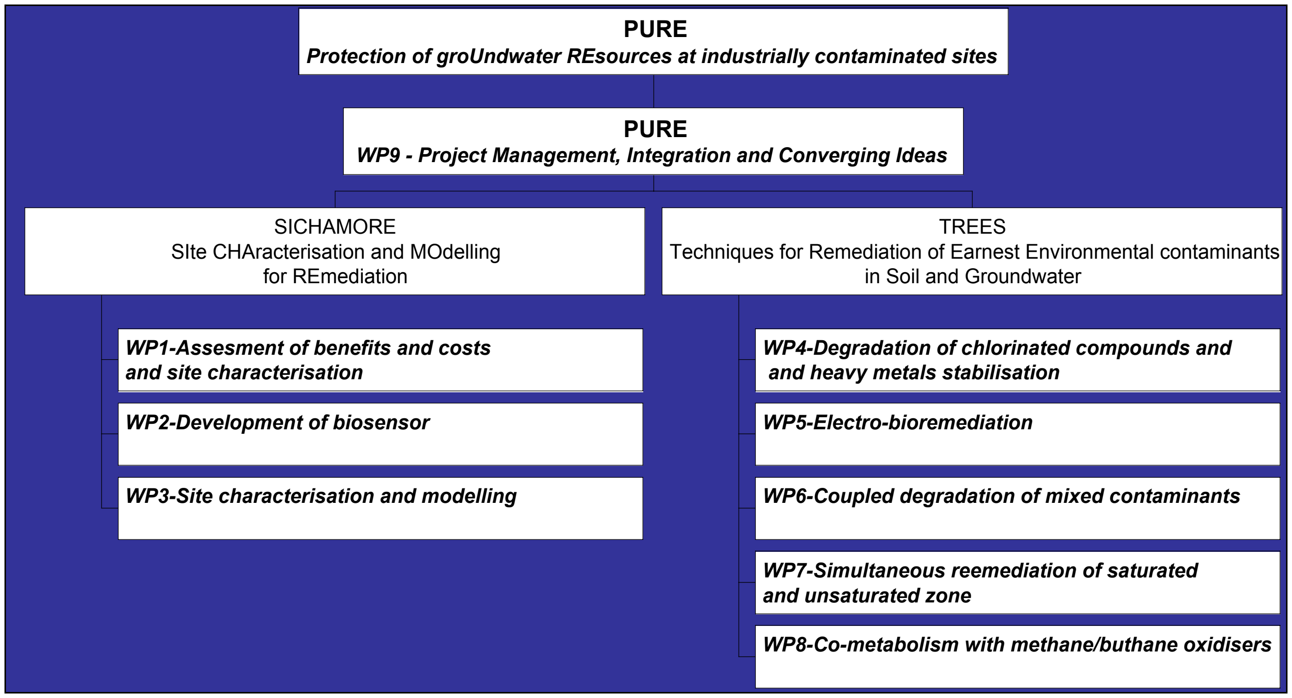

Figure 1 – project set-up

Goals of the Workpackages:

Workpackage 1: Assessment of Benefits and Costs and site characterisation
This work package is aimed at the elaboration of tools that can be applied as part of groundwater management strategy at large (contaminated) industrial sites. The first part, “ quick scan”, is structured database set-up for data collection and parameter evaluation at sites. This database is used in the ABC tool, a software product that can be used to evaluate different remedial options for one site.

Workpackage 2: Biosensors and field based analytical methods
This workpackage focuses on the field based analytical measurements with biosensors in a monitoring

activity. The combination of biosensors with rapid low-cost analytical methods will help the fast identification of the contamination and the possibilities of remediation.

Workpackage 3: Site characterisation and modelling
The aim is to develop an efficient multi-stage sampling methodology using a novel fuzzy areal site assessment (FASA) approach to reduce remediation costs as to minimize the risk of overlooking parts of the hot spots, which may imply health hazards. The second aim is to use a numerical simulator to model the development of groundwater organic contaminant plumes in the selected sites both in presence of the natural attenuation processes, as well as in response to specific remediation activities.

Workpackages 4 to 8
Several techniques are applied at different sites:
Microbiological, electro-bioremediation, coupled biodegradation, thermal/ solvent flushing, methabolic degradation are applied at the different sites and the results used and in the first three work packages.

Workpackage 9 is the project management of PURE and the benchmarking of the different WP results: both the trend of market for remediation technologies and the evolution of the relevant legislation.

ABC-TOOL

Introduction

The "ABC" is a software tool that can be used to evaluate different remedial options. It is developed as decision tool to assess benefits and costs for different site-specific remedial scenarios. It helps identify and evaluate the remediation projects and allows the comparison of the identified remediation scenarios according to clear, objective technical and economic criteria. It will assist the engineer and asset manager to optimally develop and monitor the selected scenario. An initial phase, based on the site characteristics provided by the owners, gives information on the possibility of natural attenuation and of the eventual necessity of active remediation. A matrix is formulated that includes the multiple aspects of benefits and costs. As result, the direct benefits for the industries are considered, as well as the societal benefits such as a reduction of emission, decreased amounts of polluted groundwater and of 'spilled' groundwater and lower volumes of final solid waste and waste water etc.

Modules

The ABC tool exists of 3 modules:
Assessment
Benefits
Costs

Assessment

In the ABC-tool the feasibility of remediation techniques combined with different subsurface circumstances and with different contaminants can be determined for a specific site. The ABC tool combines subsurface site data and technique characteristics. For each contamination a remediation scenario has been elaborated consulting a database. This database has been set up with the expertise and experience of experts in remediation techniques. This database is still being expanded. The variables included to show feasible techniques under specific site circumstances are described in table 2.

Table 2 - distinguishing site characteristics for determination of feasible techniques

Parameter	Unit	Description
Site		
Name	[-]	Site identifier
Country	[-]	The country where the contaminated site is located: in connection with costs
Site extent contaminated area	[ha]	This is the extent of the area of the contaminated site
Site use	[-]	Measure of intensity of use en accessibility
Receptor	[-]	Is an immediate receptor involved on or close to the contaminated site, like surface water, inhabitants (inhalation hazard)

Groundwater		
Groundwater level	[m]	Groundwater level
Groundwater flow velocity	[m/y]	The flow velocity of the groundwater, with high flow velocities (>40m/yr) some of the remediation techniques are not effective
Contaminant description		
Class	[-]	The 'class' of contaminant is chosen here. The classes are chosen by the behaviour of the contaminants and their toxicity. The environment the contaminant is in (aerobic, methanogenic, iron-sulphate reducing) is combined with this contaminant, because this is important for the feasibility of the biological remediation techniques.
Depth	[m]	The depths between which the contaminant is located.
Stage	[-]	This variable is divided in source: pure material, and plume (without source): material dissolved in the groundwater.
Zone	[-]	Is the contaminant located in the saturated or unsaturated zone.
Location	[-]	Is the contaminant located in high or low permeable soil.

Benefits

For determining environmental benefits in the B module of the ABC tool, Life Cycle Analysis is used for each remediation technique. Life Cycle Analysis (LCA) techniques analyse the environmental aspects of a product or process from gaining raw materials (the cradle) and re-use till waste processing (the grave). LCA gives an extensive understanding of what a remedial action or polluted area means in terms of environmental load. The result gives a good overview of all processes incorporated in a remediation operation. Therefore it can be combined well with other techniques analysing soil remediation. The environmental load is determined using detailed data about the remediation techniques. The Benefit module also comprises the clean up factor, the deployment of space and time in the remediation operation. The environmental data, complemented with information on cleaned soil, space and time, give the user a clear impression on possible impacts on the environment, health and welfare, caused by the remediation operation.

Costs

Cost Analysis is used for the C-module of the tool. Average costs are determined for each remediation technique. An indication for several European countries of the costs of the remediation techniques is incorporated.

Overall

Output of the ABC tool is a set of tables and graphs with information about energy, water and resource requirements, emissions and (hazardous and non-hazardous) waste. Results on the 'environmental score', time duration, deployment of space and costs are also displayed in the output (figure 2).

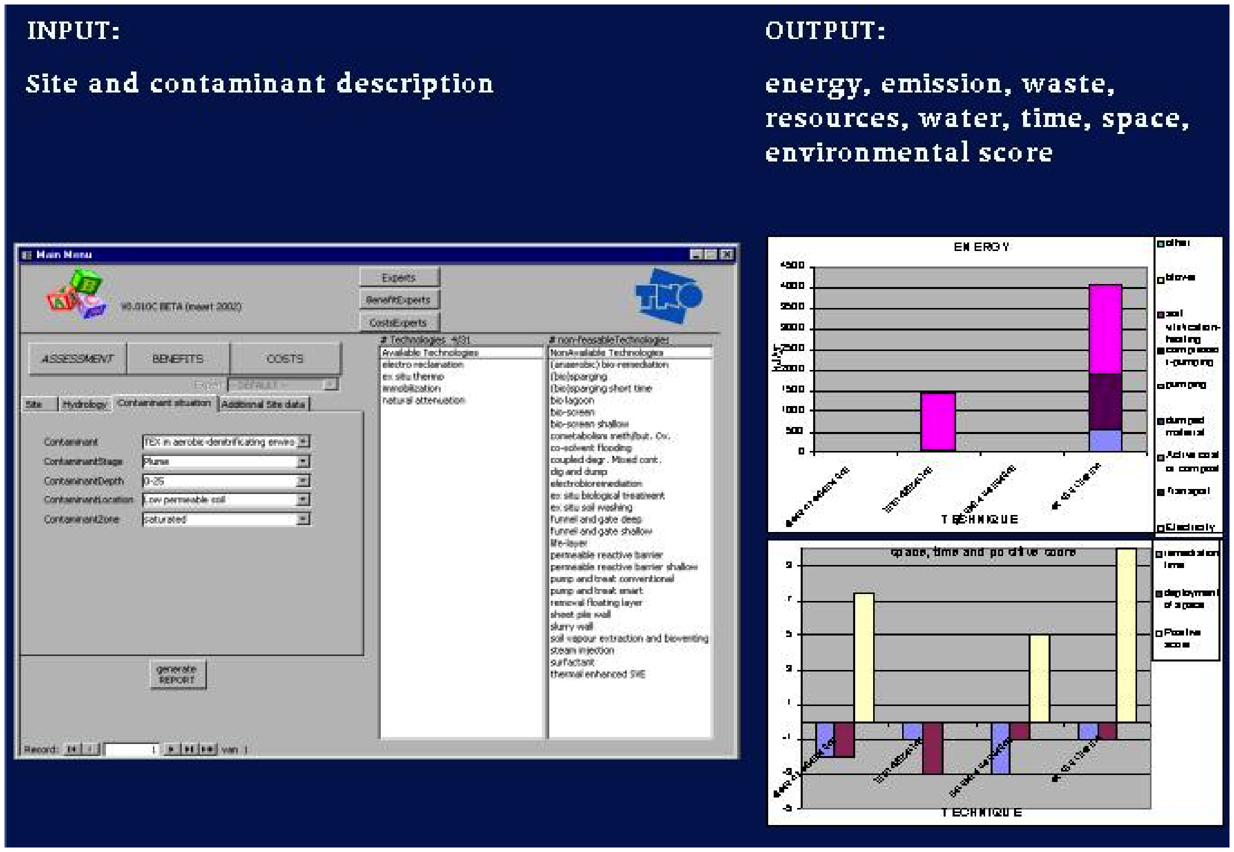

Figure 2 - Example of in- and output of the ABC tool

SUITABILITY OF ABC-TOOL

In table 3 a schematic representation of decision levels has been formulated that shows a breakdown of the flow of activities, criteria and the responsibilities of the different steps taken in this process and where this links up with the responsibilities of the management of an industrial plant. A clear insight in the way decisions are taken and the concomitant authorisation levels, is important for the end-users of PURE and helps the involved industrials to position and incorporate the deliverables of the PURE project into their daily practise.

A stepwise approach of the Site Characterisation Approach for Recovery of contaminated industrial sites (SCAR) is described to underpin a robust and cost-efficient management system at a contaminated industrial site.

Decisions and authorisation level.

For decisions and authorisations on land management of contaminated sites different management levels in the organisation are responsible. One of the expected results of the project PURE is to supply information to underpin the technical and business decisions relevant to the evaluation process of the decision makers / site owners.

An important aspect is that the adequate information is generated for the relevant decision level of the plant. Obviously, the required measure of technical detail of the information depends strongly on the type and level of the decision to take. In table 3, the different levels of decision are shown related to land management of contaminated sites comprising: assessment, combating and monitoring a soil and groundwater contamination.

Table 3: Overview of the different decision levels and activities relevant for land management and the required technical information, authorisation, time frame and monetary value.

	Decision	Activities	Techniques	Authorization	Time	Monetary value (Euro)	Aggregated information (scale)
Management decisions, company strategy							

Business Decisions	**Strategic decision (company level)**	Different sites comparison of different plant activities	Politics, Portfolio Balanced scorecard Options theory Multi criteria analysis Gut feeling	Corporate management	Years	> 10^6	sites
	Asset management or Operational level of the plant	Combination of remediation with plant production process, external contact	Decision analysis Decision making Value generation Value protection Value of information	Plant management	Months - year	10^6	One site
SCAR: Site Characterization Approach for Recovery of Contaminated Industrial Sites							
Technical decisions	**Project level:** Assessment, implementation and monitoring	Planning, HR, financial aspects, HSE, legal aspects Contact on plant (Internal) level, neighbours	Critical path analysis Cost/benefit analysis HR planning Project monitoring and evaluation Production schedule	Project management: Multidisciplinary teams management	Week	10^5	Areas
	Single activity (installation of wells, laboratory tests, experts interpretation, etc.)	Implementation of single activities within the remediation alternatives Contact on project level	Site maps Methodologies Tools Pilot tests Integrated monitoring systems	Technical expertise	Day	10^4	Layers and m2

HSE: health, safety and environment; HR: human resources

The decision maker at the plant operational level can start with the decision analysis activity once an overview of all available information relevant to the nature of the decisions is available. A fast simple assessment has to be made in a first phase of the project resulting in a risk, benefit and cost analysis. A multidisciplinary team of technical experts will create and analyse this information during this initial phase of project. During the process the team will work together with the decision maker to optimise the remediation in terms of technical, financial and timing criteria and to meet both internal and external constrains. These constrains can be addressed more in detail during the second phase of the project.
The Site Characterisation Approach for Recovery of contaminated industrial sites (SCAR) will focus on the technical management level of the site. The final results, however, will be presented to the management of the plant where the final decisions are taken, depending on size to be authorised by higher management levels.

SCAR: Site Characterization Approach for Recovery of Contaminated Industrial Sites

The PURE project the main activities are directed at project level and single activity level. The SICHAMORE part of the project PURE will generate data and give added value to the site owners to allow for making a decision on the remediation of the contamination. SCAR:

- Contributes to the formulation of a comprehensive and structured overview for the sites in the PURE project;
- Gives an overview of the different steps of the site characterization that could be applied on different sites and could be adapted according to the needs of the site owner;
- Comprises an inventory of existing and historical site development;
- Indicates possible site remediation scenarios with associated technical and financial uncertainties;
- Will enable the decision-makers to perform sensitivity analysis and test the robustness of the individual site remediation alternatives in terms of opportunity and risks.

Apart from the financial risks, like (internal) site information related to remediation alternatives and their financial aspects, also the human health, toxicological and environmental related risks are addressed. These risks are important indicators for the internal- (industrial plant) and external stakeholders (municipality, neighbourhood, water company).

SCAR has been developed to enable the results of the PURE project to be integrated and efficiently used by site owners to take the relevant decisions for site management. The project results show what input, activity and criteria are needed to obtain an output that meets the expectations of both the developers and end-users of the project as much as possible. The approach is divided in three main phases. Phase 1 gives a first fast, relatively cheap, impression of the risks, benefits and cost of the remediation of the contamination involved. Phase 2 gives the risks (technical, economical, HSE, political), benefits and costs more detailed. In phase 3 field test are carried out at the site and the site is actually remediated (table 4).

Table 4 - General phasing of SCAR: Site Characterisation Approach for Recovery of Contaminated Industrial Mega sites, and working packages relevant for the development of the phases.

	Activity
Phase 1	Historical data collection Sampling campaign (somewhat rough) Risk analysis and rough modelling on the basis of FASA Sampling (more detailed) Simple ABC check
Phase 2	Request for more investigation Detailed measurements Final risk analysis ABC check and presentation of alternatives (scenarios)
Phase 3	Pilot trials Final design Implementation

Project approach for SCAR

In table 5 the version of SCAR is presented in more detail and the activity, knowledge provider and output of each step is given. Phase 3 is site dependent and not included in table 5. The steps are described in detail in the following paragraphs.

Table 5 - Draft of SCAR: Site Characterisation Approach for Recovery of Contaminated Industrial Mega sites

	Main activity	Activity	Knowledge provider, input	Output
PHASE 1: Quick Scan				
Rough characterisation phase **Risks rough** *** Fast** *** Cheap**	Assessment existing data; historical data	Information collection and gap analysis, analysis of health risks	Site owner, Aquater	Preliminary conceptual model
	Sampling field campaign ↕	Rapid sampling and filling in the gaps	Universities: Cranfield and Aberdeen via ICI	More efficient characterisation methods
	Assessment of spatial risks ↕	From general to detailed assessment of sampling campaign design	Yeditepe Univ. FASA, Aquater, Technical input from TREES	Refined conceptual model
	Simple ABC check	Different remediation scenario presentation with advantages and disadvantages	TNO Input of costs from TREES	Preliminary ABC, preparation of T.o.R. Phase 2
PHASE 2: Evaluation of remedial scenario's				
Detailed characterisation phase **Balanced risk assessment** *** Time consuming** *** Expensive**	Detailed field measurements ↕	More detailed implementation of site	FASA	Final conceptual model
	Design of remediation scenarios and monitoring plan ↕	Fate and transport modelling, sensitivity design, risk assessment	Aquater	Number of alternative remediation scenarios with advantages and disadvantages
	Suggestions on asset management level **ABC product**	Elaborated advice on remediation **Assessment, Benefit and Costs**	TNO Input of costs from TREES	Remediation scenarios, tech. and fin. risk, time, C-B relations

Interaction between the activities ↔

Phase I: quick scan

In order to achieve a preliminary description and understanding of the site and be able to plan further surveys and activities, it is necessary to collect and examine existing documents and reports and carry out preliminary inspections both on site and in the immediate surroundings.

Information and documents to be collected should include:

- Detailed maps of the area in the present conditions;

- Historic maps documenting the major phases of site (use) development;
- Calamity review, interviews;
- Maps reporting buildings, roads, plants and facilities (storage tanks, pipelines, sewers, loading and unloading areas, etc.);
- List of substances used in manufacturing, produced by the plants and to be disposed off, possibly over the entire period of site use; collection of data on their hazard and toxicity.
- Location of landfills present in the area, with description of type and volume of wastes and technical information on landfill characteristics;
- Present and future use of site and surroundings according to urban plans;
- Technical documentation related to geological, hydrogeological, geotechnical and environmental studies performed in the past for site construction or during site development.

The site-specific information should be complemented by the collection of existing data related to the surrounding area and environment:
- Geological and hydrogeological framework of the site and its area of influence at regional and local scales;
- Location of wells used for groundwater withdrawal and collection of data on their characteristics;
- Collection of data on shallow water bodies and natural environment;
- Aerial photogrammetric surveys;
- Analysis of population distribution in the area and of other anthropic activities, and identification of possible targets of groundwater and atmospheric contamination.

All the information and collected data should be analysed and integrated to construct what is called a 'conceptual model' of the site. In a wider sense, the conceptual model of a contaminated site should be build as a necessary basis for any modelling activity and useful multidisciplinary representation of the subsurface system. This model should be used as a basis for planning characterization and monitoring activities, and to define alternative plans for the management of the contamination.
The 'conceptual model' of a contaminated site is a schematic picture of the real system. As the knowledge of the real system improves in time, the conceptual model needs to be updated and should be viewed as a continuing process.

Within Phase I, the preliminary conceptual model of the site comprises the main information regarding the geology and hydrogeology of the site and all available data about the location of plants, storage tanks, pipelines, and so on, that were possible sources of contamination in the past. The site picture obtained is the foundation for the planning of characterisation surveys in which the sampling points are concentrated. This will be the case in those areas which are likely to be contaminated (assessment of likely hotspots), and for the chemical analysis program that will focus on the most hazardous substances. This step includes the assessment of a health and environmental risks: Is there a possibility of contamination of the drinking water supply or can surface water be polluted. The term risk depends on the perception of all the stakeholders and should be carefully assessed.

Apart from the geological and hydrogeological features of the site, the preliminary conceptual model should include:
- The identification of areas which are likely to be sources of contamination;
- Location of subsurface sources (NAPL pools, residual NAPL, contaminated filling materials);
- The identification of contaminants which are possibly present in the unsaturated zone and are possibly dissolved in the aquifer forming plumes transported by groundwater flow;
- Identification of pathways and boundaries for contaminant transport;
- Identification and description of targets to be protected;
- Definition of (health) risks involved;
- Definition of remedial targets in agreement with the local environmental legislation.

Sampling field campaign
Whilst the biosensor approach is valid for identifying toxicity hot spots on site, further qualitative and quantitative identification of contaminants is required to provide a full site characterisation. Based on assessment of existing data, the nature of the contamination and the probable contaminants present may first be elucidated. Many VOC/SVOC contaminants may be determined by commercially available field-based immunoassay test kits that are simple to use, specific, sensitive and are low-cost.
To supplement the organic contaminants programme, in situations where site contamination by heavy metals is suspected, the use of rapid low cost electroanalytical methodologies can be deployed. Key

heavy metal species can be measured using disposable screen-printed electrodes with a minimum amount of mercuric salts present (1-2 μg Hg).

Assessment of risks and conceptual model

The newly developed Fuzzy Areal Site Assessment (FASA) approach is used to reduce the investigation costs and to minimize the risk of missing (parts of) hot spots, and not increase the cost of the installation of too many investigation wells. The FASA approach is used to design an additional sampling campaign focussed on efficient data gathering at a minimum cost with a limited number of drillings (wells). The risks of missing hot spots and the costs involved could be high if a detailed measuring campaign is started at this stage.

To downsize these risks the site-specific data collected about the contamination are used to update the conceptual model.

Conceptual models in risk analysis activities

The risk analysis has a main target to estimate the health and environmental risks associated with site-specific contaminants. To estimate the risks, the contaminants concentrations over time at the target locations must be predicted in a reliable way. This estimation needs a comprehensive understanding of site geology and hydrogeology, of contaminants distribution and their environmental characteristics, the identification of pathways and of the targets located around the site that ultimately can be reached by contaminants.

Using mathematical models, from simple analytical models to more complex numerical models, predictions are made. In this context, the conceptual model of the contaminated site can be considered as the site schematisation that incorporates all site characteristics, the contaminants distribution, the possible pathways and the targets.

The *refined conceptual model* is the updating of the preliminary model using additional field data collected by the sampling campaign and rapid analysis of soil and groundwater and supported by the FASA data processing. This refined conceptual model supports the definition of the plans for more sampling and analysis in selected site areas.

FASA data processing and the modelling exercise results in an efficient sampling campaign and it reduces the risks.

At the second phase of development, the refined conceptual model can be seen as final once the major site characterization activities have been completed and that further activities are limited to the already studied areas. The collection of additional data is only necessary in case the design of remediation systems or monitoring purposes so dictates. The refined conceptual model should be periodically updated.

Simple ABC check

The first Assessment, Benefit and Costs (ABC) provides a decision alternative with the collected data and refined conceptual model for the plant management. The purpose of this first phase is to establish a budget for the coming period, gives a first idea about the possible financial liabilities and to inform the authorities concerned. This first impression will, in general, be relatively fast and low cost. The first possible remediation alternatives are defined with risks. The nature, distribution and extent of contamination will influence the final selection of remedial actions. Hence after the data collection is completed adjustments of remedial scenarios may be needed.

The output of this phase is:

- Delineating contaminant source areas and release characteristics
- Defining the nature and extent of contamination
- Investigation on by whom and when the contamination was caused
- Characterizing contaminant transport pathways, processes and rates
- Estimating the risks associated with contaminant transport
- Assessing aquifer restoration potential
- Gap analysis on data
- HSE risk identification
- Multi-scenario development with benefits and costs
- Estimation of time related to the different remediation scenarios
- A business decision can be made and priorities indicated at the asset management level.

Phase II: evaluation of remedial scenario's

Detailed field measurements at selected areas
The result of the refined conceptual modelling together with the first ABC check will be used as the input to design, tender and implement a sampling campaign. This sampling campaign is needed to obtain sufficient data to fill the gaps in the risk assessment study, which will include the Fate and Transport modelling.

Detailed surveys are performed at this stage of the Site Characterisation on the basis of the first phase of the study. They will include sampling and laboratory analysis on new soil and water samples, the execution of specific hydrogeological tests and geophysical surveys to characterize local geology and hydrogeology.

The *Final conceptual model*, should result from the incorporation of the refined model and of all those data and results coming from the execution and interpretation of detailed surveys performed. The final conceptual model should be the basis for the risk based analysis and thus for the use of fate and transport models necessary for a reliable assessment of risk scenarios developed for the site. The conceptual model can be seen as final in the sense that major site characterization activities have already been performed and that further activities should then be limited to detailed surveys in portions of already studied areas, or be executed for monitoring purposes or to acquire specific data for the design of remediation alternatives.

The Risk Assessment analysis, including the Fate and Transport modelling, and monitoring design will downsize the number of alternatives and will generate more information on the effectiveness of the remediation techniques planned. This step also includes the set up of a monitoring strategy and the performance of any additional specific laboratory or field tests and surveys.

Fate and transport modelling in the frame of risk assessment studies
The main target of risk assessment is to evaluate the health and environmental risk associated to the exposure at site-specific contaminants reaching recognized target locations through identified exposure pathways. Thus, contaminant concentrations over time at the target locations must be predicted in a reliable way for extended period of time. These evaluations, of contaminants distribution and their environmental characteristics, are performed by using mathematical models, from simple analytical to complex numerical models, to predict the transport of contaminants along the identified pathways such as surface water bodies, the unsaturated zone, the groundwater, the atmosphere, etc.
In this context, complex numerical models are used in complex risk assessment procedures and when reliable answers cannot be obtained with simple analytical models.

Decision on asset management level of remediation Assessment, Benefit and Costs (ABC tool)
The final step[of phase 2 is the application of the ABC tool, however this time with more detailed information.
It allows for the comparison and relative ranking of the identified remediation scenarios according to clear, objective technical and financial criteria.

The results of the ABC tool comprises:

- Selection on specific site characteristics and the feasibility of remediation techniques
- An overview of benefits of technically feasible remediation techniques for a specific site
- A scoring of benefits for different users
- An overview of costs of technically feasible remediation techniques for a specific site
- Financial variables can be integrated with the technical variables to generate an expectation curve for the Net Present Value.
- An overview of the HSE risks, technical, economical risks
- Comparison between areas of sites and techniques
- Survey of pros and cons of remediation techniques
- Support to allow site owners to make an evaluation on environmental load and merit and economical variables

Conclusions

The tool allows insight in contaminated site issues and choices for remediation techniques. Using the information on possible remediation techniques, in terms of benefits and costs, the most cost-reducing and environmental sound remediation solution can be chosen. The environmental aspects are considered not only in costs, but also the environmental load and merits caused by a technique, duration and occupation of the site. This is one of the most important reasons why the ABC tool aids communication with involved parties. The different aspects can be compared according to importance for the interested group to show the sensitivity of decisions taken or proposed.

The introduction of new innovative biological techniques is another important advantage of using the ABC tool. New techniques can be compared with traditional techniques on costs and benefits. This can enhance the social acceptance of e.g. a technique that has long duration but reduces costs and is no hazard to environment and human health.

This makes the ABC tool a:

Technical tool

- To evaluate different remediation scenarios
- To evaluate different techniques (physical, chemical, biological)
- To evaluate different innovative and state of the art techniques

Communication tool

- To compare remediation with different aspects

Economic evaluation tool

- To evaluate cost effectiveness
- To evaluate the time aspect
- To evaluate space deployment

CONCEPT OF SUSTAINABLE DEVELOPMENT FOR TARNOWSKIE GÓRY MEGASITE - POLAND

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Tarnowskie Góry Megasite is a representative case for the environmental problems in the Upper Silesia region in the matter of soil and groundwater contamination with heavy metals and other inorganic pollutants. These problems varies in the region according to historical development patterns and environmental conditions. Many years of industrial activities resulted in:

- heavy changes in the geological structures and water regimes - due to coal mining activities,
- soil contamination - due to atmospheric pollution loads,
- land changes - connected with industrial operations and structural development,
- groundwater and soil contamination - due to landfilling of industrial and urban wastes.

Virtually the whole area of Upper Silesia is affected in one way or another by these problems. They are of different scale and scope. They have different socio-economical impact on current and potential development. In the region, there can be differentiated heavily polluted hot spots and areas with relatively mild, diffused contamination.

Tarnowskie Góry mega-site has all presented above features. Thus, it is a good case to work out rules of sustainable development for the whole region in the scope of soil and groundwater contamination. In principle sustainable development means that social, economical and environmental aspects are taken into account in a decision- making process (Janikowski, 1998; Janikowski, Korcz, 2002; Janikowski, Korcz, 2003). Solving of soil and groundwater problems in the region should take into account those three perspectives. In practice it means that in the decision-making processes there should be included:

- current state of the environment,
- socially - oriented values of the environmental resources (soil and groundwater),
- available economical resources, which could be spent on the remediation activity.

It should be marked that for most of the soil contamination problems complete clean-up operations are not practical solution in the region. Remediation options are determined by environmental and technical factors (Kivell, Hatfield, 1998; EEA, 2000).

The main goal of development on the post-industrial sites including the Tarnowskie Góry Mega-site is revitalisation of derelict land with minimalisation of the environmental risks to protect groundwater resources and human health (Figure 1). In general the concept of sustainable development is based on the idea of cost-effectiveness. It requires a better understanding of effects and costs in the process of decision-making (Janikowski, Korcz, 2002; Janikowski, Korcz, 2003).

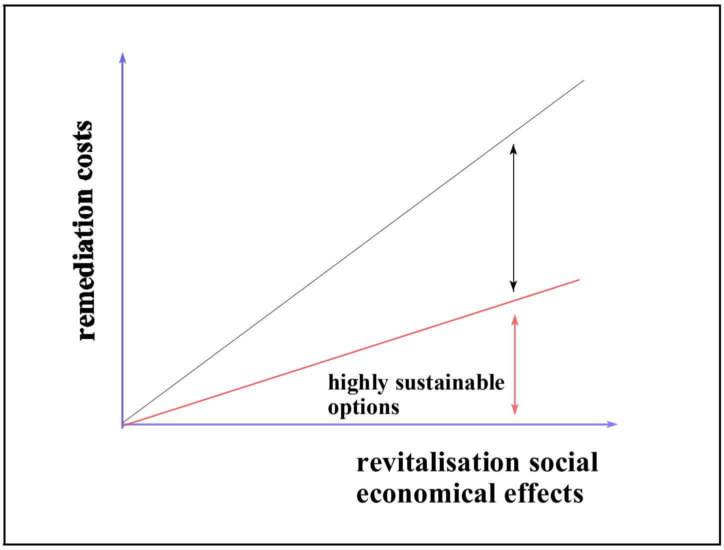

Figure 1 Cost-efficiency as the driving feature of sustainable development on the Tarnowskie Góry site

Accordingly the concept of sustainable development includes four site-specific elements (Figure 2):

- socially -oriented valuation of environmental assets (fit for use approach) based on their environmental status determined according to currently available characteristics,
- determination of critical parameters of development - goals and boundaries of development (environmental quality, economical conditions, social needs),
- detailed and targeted assessment of the environment quality, based on GIS system with input from existing monitoring systems enhanced with supplementary site-specific systems.
- continuous management, based on existing system of administration and legal instruments.

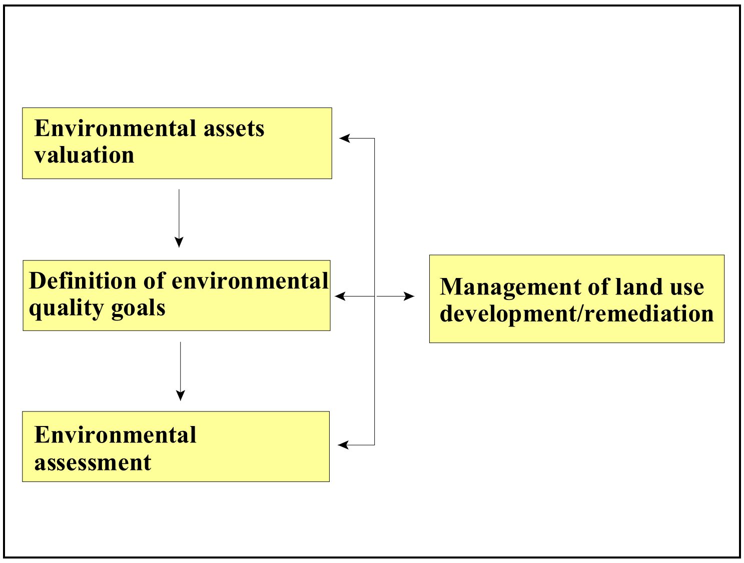

Figure 2 Management scheme for sustainable development on the Tarnowskie Góry site

Realisation of this concept requires appropriate administrative adjustments in the regional management system in such a way as to secure economically sound, technically feasible and ecologically and socially effective development of the region.

In environmental assets valuation the criteria of the environmental quality, their importance to local, regional economy, development and quality of life are taken into account. In the test site Tarnowskie Góry environmental resources are of importance in the following order:

- groundwater resources,

- soil resources,
- forests and ecosystems,
- surface waters (with exclusion for a small size catchment).

Groundwater resources in Tarnowskie Góry are the priority of environmental policy at a local and regional scale (COTG, 2002). It has wide local and regional public and administration attention. The groundwater in two aquifers is a source of drinking water for Tarnowskie Góry and other Silesian cities (approximately 100.000 inhabitants). There is a strong anthropogenic impact on groundwater caused by various pollution sources.

Agriculturally used soil is important only on a local scale because agriculture has marginal importance for the local economy. The agricultural area covers 41% of the Tarnowskie Góry Mega-site. Around 50% of the soil is assessed as degraded by industrial contamination with heavy metals and restrictions on the usage are imposed by the authorities. Forests cover accordingly 43% of the area and are important in the aspect of nature protection, recreation and forestry activities with locally important wood processing economy. Some parts (5% of the forested area) are highly degraded due to soil contamination with heavy metals (around 50% of the area impacted in different range) and general anthropogenic impact (COTG, 2002).

Surface waters are used only for a small part as a drinking water sources. Protected catchment area covers only 5% of the site. Surface waters have some importance in nature protection. They are, to some extent in contact with groundwater bodies but the interaction is not essential in terms of water quality. There exists the problem of pollutants accumulation in sediments of rivers, hampering the water ecosystem revitalisation.

Environmental risks in case of surface water, soil and forests does not impact development in the Tarnowskie Góry area in a critical way, having in mind that most of the initial causes of pollution are extinct now. But the land cover determines the overall impacts on groundwater especially in the case of metals and other mobile contaminants.

The reference levels and goals for the groundwater quality aquifers being at risk are primary based on the requirements established by Polish law concerning drinking water and groundwater quality. The aquifers are endangered by emission of nitrates, metals and non metals from various pollution sources. The assessment shows clearly that quality deterioration is taking place.

To build up the management system for the test site classification of pollution sources was carried out. The following criteria of groundwater assessment and management were used:
impacts:

- type of contamination emitted to the environment,
- type of contamination source,

risks:

- potential spread of contamination in the soil to groundwater scenario, (mass flux, contamination plume characteristics),
- buffering capacity of the environment (land cover characteristics, sorption capacity of the aquifer, biodegradation capacity),
- risk posed to groundwater utility function (changes in the groundwater quality, contaminant concentrations toxicity characteristics),
- the uncertainty factor (data and knowledge),
- risk posed by the contamination (receptors, real and potential scenarios),
- extent of the problem in spatial terms,

policy factors:

- problem weight in the local development context (land value, environmental assets),
- manageability of the problem in the context of management options, land-use options, activity patterns, available costs.

The contamination sources were clustered according to these criteria. According to this criteria Mega-site Tarnowskie Góry comprises three different types of groundwater pollution according to the chosen criteria:

- point/linear sources of pollution,
- diffused pollution sources,

- degraded areas (extensive hot spots).

The input to the groundwater of contamination from the three sources varies. Those sources can produce unacceptable levels of contaminant concentrations in the aquifer but only the degraded areas are characterised sufficiently enough to make proper assessment. Currently, for point sources there is not available sufficient information representing the whole site and covering the whole spectrum of the problem (Table 1). Apart from landfills and waste heaps, other point sources are difficult in identification. In the area there are located many small enterprises, which potentially can be a source of pollution, due to bad maintenance, and inappropriate behaviour of the owners. The enterprises are operational and dispersed in the whole area. Their impact on the environment is individually rather of a small scale but the aggregated impact is uncertain.

It can be envisioned that the problem of point sources will be to some extent tackled by strengthening Polish environmental law with new environmental legislation and its execution. The groundwater quality in the area is controlled now by tree types of control: sanitary control of well used for water abstraction, sanitary control of individual wells and monitoring system of groundwater quality in the aquifer.

Table 1 Point sources characteristics

Criterion	Characteristics
Contamination	chlorinated hydrocarbons, hydrocarbons, heavy metals
Type of source	small enterprises, petrol stations, washing services, repair stations, wood processing plants, food processing plants, landfills, military installations, medium chemical industry: pulp production, chemical agent production
Buffering capacity	medium
Data quality	incomplete, potential sources are identified, information on contamination profiles of the sources is uncertain, no integrated inventory
Spread of pollution	limited, probably essential, according to existing monitoring no processes detected
Spatial extent	separated, local
Risk	exposure identified in two main water abstraction points, other main and individual local water abstraction points may be endangered
Problem importance	important
Manageability	medium
Management options	cycle procedures of contaminated source identification assessment and management:, contamination source clean up.

In Tarnowskie Góry Mega-site the diffused pollution sources cover a vast area. The problem comprises mainly soil contamination with heavy metals of industrial origin and agricultural waste and household sewage emission (Table 2). According to the available data metals from diffused sources do not pose immediate danger. The problem is well characterised because the issue of soil contamination was viewed so far as priority in the context of local agriculture and health risks connected with polluted food. The agriculture activities are now restricted by the administration on a voluntary basis. The mobility of contaminants in the environment is relatively low, so the scenario of contaminants migration from soil to groundwater is not the priority now.

More important are agricultural and individual households waste and sewage management impacts in rural and suburban areas. The problem is aggravated in some areas threatening local water abstraction.

Table 2 Diffused sources characteristics

Criterion	Characteristics
Contamination	nitrates, pesticides, heavy metals
Type of source	agriculture, waste water discharges from individual households in the rural areas, polluted soil
Buffering capacity	medium/high
Data quality	fair characteristics and estimations
Spread of pollution	limited, probably essential, no information according to monitoring
Spatial extent	separated, local
Risk	no exposure detected, local water abstraction points may be endangered
Problem importance	important
Manageability	low
Management options	control procedures of assessment and management: source characterisation, environmental characterisation, land-use management, activities management, infrastructure development improvement.

Degraded areas (extensive hot spots) constitute the most immediate and socially valid problem to be solved in the Tarnowskie Góry site (Table 3). The most important is the area of the former factory in Czarna Huta district. It is well characterised problem. It arose as a result of metal processing activities. This area has a long history of industrial development from XIV century, including ore mining, chemical production, pulp processing. Currently the main environmental problem is the deposition of metals and non metals in the geological structures, threatening two important triasic aquifers with contamination plume development between 6-14 square km, depending on the contamination, around the source area. Elimination of the waste deposits, which were originally the cause of the contamination is being carried out. Although, the quality criteria fulfilment is required by law in generic terms in the area, there is a need to exclude the contaminated area from the administrative regime as a special risk zone.

Table 3 Degraded areas characteristics

Criterion	Characteristics
Contamination	Barium, Boron, Strontium, heavy metals
Type of source	industry: Czarna Huta, industrial wastes
Buffering capacity	low
Data quality	source area is well recognized and characterized – impacted area described with essential uncertainty
Spread of pollution	high risk of plume enlargement in the aquifer
Spatial extent	local, around the source area
Risk	water abstraction functions essentially hampered in the impacted area, water abstraction were closed down
Problem importance	high importance – regional scale
Manageability	medium
Management options	source clean up, pump and treat solutions, plume containment

Although the contaminated groundwater is located under the city it does not pose an immediate threat to the population because the water for the Tarnowskie Góry supply system can provided from wells located 10 km from the contamination source instead of using the impacted wells. To some extent it is a good situation that the supply pattern is not dominated by individual system in the contaminated area.

Prioritisation of the management activities should be as follows:
- degraded areas,
- point sources,
- diffused pollution sources.

As it was presented all three types of contamination source require three sets of site management measures in dealing with the pollution problem (Table 4). The scheme of management can be put as follows:
- building up inventory system of the existing and potential pollution sources,
- harmonization and integration of groundwater quality protection and remediation with other development issues.
- environmental control measures.
Those three elements form the basis for case oriented- assessment and management procedures.

Table 4 The manageability options for contamination sources

Type of source	Management options
Point sources	management procedure comprising identification of potential pollution sources, monitoring measures, cost-efficient source identification methods, education and information measures
Diffused sources	land-use management, environmentally sound practices, education and information measures
Degraded areas	source extraction in realisation, Pump and treat measures, control diffusion of residual contamination of highly mobile contaminants, control measures

The key aspect in the management is control of groundwater quality status and control of the contamination paths between various media. The incomplete characteristics of the site reduce the capability of management. There should be stressed that a lot of pollution sources can be unidentified and difficult to describe on the base of historical analysis. The manager must take into account possibility of unidentified sources occurrence Environmental assessment should be implemented as a cycling approach. In groundwater quality management of all contamination source clusters land use and human activity issues are a crucial factor. Soil and land cover determine the buffer capacity preventing emissions of contaminants to groundwater.

Conclusions

The boundary conditions of the mega-site Tarnowskie Góry management are very strict in economical and social terms. Costs are the crucial factor in the management of contaminated land in the Tarnowskie Góry site. They comprise costs of monitoring, assessment and management, including remediation activities. The available locally financial sources are very limited. All activities carried out on the Czarna Huta site, concerning only securing the industrial wastes will cost approximately 115 million €. Only a small part, around 5% is covered by local administration. It means that the management system for the whole site governed by county administration must be highly cost-efficient.

Having in mind the boundary conditions of management, for the site Tarnowskie Góry active management control–oriented would be the best option. Integration of groundwater resources protection with land-use development, control and protection measures imposed on various activities is the solution for sustainable development in the area. Integration of management measures requires use of appropriate procedures such like integrated mangement system with a long term perspective.

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References

EEA (2000) *Down to Earth: soil degradation and sustainable development in Europe*, Environmental Issues Series, No 16, 32 pp., European Environment Agency, Copenhagen.
Janikowski R. (1999) *Environmental Management*, Akademicka Oficyna Wydawnicza PLJ, Warszawa (in Polish).
Janikowski R., Korcz M. (2001) Management of brownfield remediation, *Ekonomia i Środowisko* No 1(18), p. 103-112 (in Polish).
JANIKOWSKI R., KORCZ M. (2003) FINANCING AND COST OF REDEVELOPMENT OF POST-INDUSTRIAL SITES IN POLAND, *LAND CONTAMINATION & RECLAMATION* (IN PRESS).
Kivell P., Hatfield S. (1998) Derelict Land - Some Positive Perspectives, [in:] P. Kivell, P. Roberts, G. Walker (eds) *Environment, Planning and Land Use,* Aldershot, Ashgate.
COTG (2002) *the Programme of sustainable development and Environmental Protection Program Zrównoważonego Rozwoju i Ochrony środowiska Powiatu Tarnogórskiego,* County office Tarnowskie Góry,

Theme D:

Short Communications

Estimating economic benefits of soil remediation by hedonic prices

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Introduction

During several decennia, industrial activities have seriously polluted the environment where we live in. Air pollution and soil degradation are common problems to deal with in industrialized countries. Both give rise to harmful effects to people living in the neighbourhood of industrial sites. Damage to soil from modern human activities is still increasing. The major driving forces are population growth coupled with urbanization, agricultural intensification, industrial activities and transport. According to the European Environment Agency, it was estimated that there were approximately 1.500.000 potentially contaminated sites in 1998. About 300.000 of them were identified. Soil deterioration is particularly important in central western and northern Europe.

Table 1 shows two confronting ways in which human risks arising from soil pollution can be assessed, i.e. a scientific risk approach and a social risk approach. Risk assessment is important since it forms the basis for priority setting in risk management. Ferguson et al. (1998) consider the scientific approach as a formal way to assess contamination risk, whereas the social approach tries to identify how the involved people perceive risk. The scientific research tries to identify the kind of polluting substances, pathways of pollution etc., by carrying out extensive site researches. In other words, risk is assessed in a formal way.
In Flanders, the "VLIER-humaan" model is (amongst others) used to assess risk. This model is comparable to other well-known models like HESP and C-Soil. However in these models the social risk assessment is limited or absent. On the other hand, the social risk approach relies on people's perceptions (intuitive risk assessment).

Table 1 Risk analysis

	Scientific risk approach	⟷	Social risk approach
	Formal risk assessment	Economic risk assessment	Intuitive risk assessment
Ex ante	Site research	1. Cost-effectiveness analysis 2. Cost-benefit analysis Hedonic analysis (indirect) Revealed choice	Contingent valuation (direct) Stated choice
Ex post	Epidemiological studies	Willingness to Pay (WTP) for a healthy environment	

The way economists try to deal with the risk problem is somewhere in between the two contrasting points of view. It tries to be formal, and therefore highly quantified, as well as based on human preferences. In other words, objective and subjective components are integrated to assess risk. Cost-effectiveness analysis focuses only on the monetary costs to realize a prior pre-emptive physical goal, i.e. a certain quality level of the soil. This principle is very popular in Europe to make decisions with respect to risk management. Cost-benefit analysis relies on the monetary costs and estimates of the possible benefits to assess whether a sanitation project can be approved because of economic reasons. Usually, monetizing the benefits is a difficult task. There are two big movements for measuring environmental benefits in a monetary way: stated preference methods and revealed preference methods.

The revealed preference methods try to uncover individuals' willingness to pay for a given non-market good (clean soil) from the individuals' actual actions in the market (housing prices). The main method that is based on this technique is the hedonic price method. It is an indirect method, since it uses data from a related market to value changes in the specific good of interest. On the other hand, stated preference methods attempt to uncover individuals' willingness to pay for a change in environmental quality in a direct way. The contingent valuation method simply asks people what they would be willing to pay for a quality improvement of the soil. This method makes use of market survey techniques. However, the latter seems to be a less reliable method than hedonic pricing, since problems of opportunistic behaviour are hard to deal with. For this reason we will only elaborate on the hedonic price method.

Until now our assessment of pollution risk has only been done on an ex ante basis. People try to assess in monetary terms possible future health problems without being sure that these will become real, in their individual case. In general, consequences of pollution are usually gauged ex post by performing epidemiological studies. Contamination has to be there already for a particular amount of time before its impact on human health will be visible and measurable. However, identifying causal relationships between a specific pollution source and health problems is still a research area under development. Once results of epidemiological researches become available, it is possible to provide feedback to the already conducted economic analyses, which try to gauge human health risk ex ante.

1 Benefits of soil reclamation

1.1 Monetizing benefits

1.1.1 Valuation models

Real estate surveyors are of the first profession to deal with the influence of contamination on property values. Mundy (1992) develops a theoretical model of the way of thinking in this sector. He states that the public response to contamination has a time dimension. Indeed, perceptions of hazards are changing over time and also depend on the distance from the source of the hazard. The value of an income-producing property is influenced by two components: the impact of the hazard on the marketability and the decrease in the income-producing ability of the property. The fall in marketability reflects the present value of the smaller income from the property. The marketability effect also quantifies the damage related to the lost opportunity to fully use of the affected property, e.g. the inability to use the property as a collateral.
However, in following such an approach, no attention is paid to consult the neighbourhood (the public) about the magnitude of it's smaller willingness to pay for the polluted property. In that sense the hedonic price method (or any another measurement method) forms a complementary approach. It estimates the decrease of the value of the contaminated property at a certain moment in time.

1.1.2 The hedonic price model

The hedonic price method is a valuation method that is often used to value environmental goods. The valuation of these goods is a difficult task since there is no direct market for the environment as a ‘good’. Nevertheless, it is possible to derive preferences for environmental goods in an indirect way. By using market transaction data it is possible to determine the willingness to pay for the sanitation of polluted sites. However, nowadays the empirical applications of this method in the field of soil contamination are particularly limited to landfills. Before proceeding, we explain shortly what this method is all about.

The hedonic price model was first introduced by Rosen (1974), and since then this method has known many refinements, that are specifically situated in the empirical application of this model. The departure point of Rosen’s model is the hypothesis that products are valued for their utility-bearing characteristics. In other words, consumers do not value composite commodities as a whole, but the characteristics, which those commodities embody. These composite commodities can be seen as bundles of characteristics. The purpose is to separate the effects of the various attributes of a good in such a way that can be gauged how changes in the levels of each characteristic affect utility. For instance a car is normally valued because of its different attributes: speed, reliability, safety, comfort, style, etc. Different cars represent different bundles of these characteristics. Our specific good of interest here is a house. The price of a house reflects several attributes, which give a house its value. We distinguish structural characteristics (size of house, number of rooms, garage space, age of house, size of garden, etc.), local socio-economic and neighbourhood characteristics (quality of schools, unemployment rate, recreational facilities, racial composition, etc.) and environmental characteristics (noise, air pollution, soil pollution or proximity to any environmental amenity or disamenity). Each characteristic contributes to the consumer’s overall utility of the good. Our specific point of interest is how a change in soil quality is reflected in these sales prices of houses. In this way, we would be able to monetize the benefits of possible soil remediation operations, i.e. measuring implicitly the value of risk reduction in a preference based manner. People’s behaviour in the housing market reveals the willingness to pay for a clean soil.

The first stage of the hedonic price method is the estimation of the hedonic price function. This is a ceteris paribus analysis that tries to identify how housing prices vary with the distance to the contaminated site. Because of the large number of the characteristics of relevance, it is important to have a large sample of houses. Here there is often a problem of data availability. The functional form of the hedonic price function is also of great importance. If it is linear then property prices are affected by a constant amount per unit change in the dependent variables. However, the functional form is usually non-linear (logarithmic, Box-Cox transformation) because of theoretical (e.g. the ability to reflect the decreasing influence of the distance) and practical considerations.

The second stage derives the marginal willingness to pay or the inverse demand function for a clean soil. From the hedonic price function, determined in stage 1, marginal implicit prices of the attributes can now be derived. These implicit prices of the attributes are the hedonic prices. The marginal willingness to pay for a change in soil quality is given by the first order partial derivative with respect to the particular attribute, i.c. soil quality. Once the marginal implicit prices are calculated, these are regressed on the distance to the contamination source and variables that describe the socio-economic background of the household (size of the household, income, education, marital status, age). The empirical application of this two-stage method is difficult, since we have to deal with problems like identification and endogeneity. First, the second stage in the analysis does not contain any new information that is not yet incorporated in the first step. Indeed, marginal implicit prices are not observed directly, but are calculated on the basis of information from the first stage. Consequently, it is difficult to distinguish between the hedonic price function and the inverse demand function. Second, marginal implicit prices and the distance to the contaminated site are simultaneously determined by the buyer of the house. This produces endogeneity problems. The use of instrumental variables (socio-economic background) and the segmentation of the market into several parts can give a solution for both problems. This makes the large number of observations even more demanding.

The inverse demand function now allows the estimation of the benefits of both marginal and non-marginal changes in attributes that embody the house. More specifically, we are interested in the benefits from the sanitation of a contaminated soil. Then, a cost benefit analysis will compare the benefits of a soil remediation operation with its costs. From an economic point of view, such a cost benefit analysis can be used to make a ranking between several polluted sites. By monetizing the benefits, we can use an economic rule to set priorities. The benefits of a reduction in pollution levels can now be calculated as the surface under the inverse demand function (derived in stage 2). The upper and lower bound are respectively the soil quality before and after the sanitation operation. However, Bartik (1988) states that the calculated benefits will only be a lower bound for the real benefits. The most important reason is that the analysis does not incorporate possible changes of the hedonic price function that occur over time. Finally, the total benefits of a soil remediation operation are then calculated by multiplying the calculated benefits with the number of houses that are situated in the polluted area.

We can conclude that the hedonic price method is a good tool to gauge the benefits of soil reclamations. However, the analysis is data demanding and asks for a lot of time to apply. Especially, the second stage has to be applied carefully in order to avoid biased results. In the empirical part (see below), we opt for a slightly different approach. We try to assess the benefits by measuring the change of housing value along the hedonic gradient, deduced from the first stage of the method.

1.2 Link with health effects

1.2.1 Health effects from nearby landfills and industrial sites

Landfills are an important pollution source that causes health and aesthetic problems when situated in the surroundings of residential areas. The possible health effects of living nearby a landfill make a lot of people unquiet, especially when the landfill contains hazardous chemical substances (e.g. heavy metals). Exposure can happen by different channels: contamination via groundwater dispersion, intake of contaminated food, air transported chemicals or substances via gas migration and in-house pollution by dust or evaporation of VOCs.

Dolk et al. (1998) show that there is a higher risk of congenital anomaly in babies whose mothers have residence near landfill sites that handle hazardous chemical wastes. However, the excess risk is small, but statistically significant. Nevertheless the question here remains open whether the effect is a causal one. Therefore a dose-response effect, in which the sites of highest hazard potential are associated with the highest risk of congenital anomaly, would give evidence for the hypothesis of a causal effect between risk of congenital anomaly and proximity to hazardous landfill sites.

Benedetti, Lavarone and Comba (2001) review the available epidemiological studies on cancer risk associated with residence in the neighbourhood of industrial sites. They found clear evidence for an association between residential proximity to major industrial sites and risk of lung cancer and lymphohematopoietic malignancies. Moreover the hypothesis that the association is causal is gaining support from other epidemiological observations.

A recent research on soil contamination coming from a lead smelter in Hoboken (Antwerp, Belgium) shows a statistically significant difference between the study group and the control group. Children between 1 and 12 years old, living in the district Moretusburg, were found to have higher lead concentrations in their blood than their counterparts living further away. Another epidemiological study in Lommel – Overpelt (Belgium) showed that chronic exposure to cadmium pollution might promote skeletal demineralization, which may lead to increased bone fragility (Staessen et al., 1999).

All this epidemiological studies have to deal with some important problems. First, there is a high degree of uncertainty about the level of exposure of the contamination to the surrounding neighbourhood. Therefore, it is difficult to gauge the dose-response effect between the contamination and health anomalies. Second, one has to be aware that the association between soil contamination and epidemiological consequences is complicated by several confounding factors, i.e. socio-economic status and personal habits. It is necessary to implement as many variables as possible in order to not distort the analysis. Third, most studies find an association between contamination and health effects. However, there is still a lot of uncertainty whether the relationship found is causal or not. In order to proof causality there is definitely a need for more data at a disaggregate level.

1.2.2 Introduction of risk perception in hedonic price analysis

The way risks are perceived by the public is of real importance in a revealed preference method like hedonic pricing. As already mentioned above, housing prices indirectly reveal people's preferences for a specific characteristic embodied in the house, e.g. a healthy and clean environment. However, it should be clear that people do not take into account real risk levels because of a lack of information and a high extent of uncertainty. In fact, it is the perception of the health risk stemming from the pollution source, which goes together with the evolution of housing prices. This perception is mainly built on information that is given by the media or politicians. Eventually it is possible that a large gap exists between real risks and perceived, just because of rumours.

McCluskey and Rausser (2001) analyse the evolution of perceived risk and its effects on property values by using a system of two equations: a hedonic pricing function and a Bayesian learning equation. The first equation tries to individualize the perceived risk to each particular house by using a proxy for it, i.e. the distance between a house and the hazardous waste site. The second equation updates people's perception of risk with the information received from the media. Indeed, it seems to be the case that the media is the dominant force in determining the public risk perception. They use a generalized maximum entropy (GME) technique to recover the unknown parameters and an unobservable state variable (perceived risk). With data from lead contaminated soil in Dallas County, they found that increased risk perceptions negatively affect real property values. This means that perceived risk is more important than the actual risk.

The well-known fact that people usually overestimate low-probability events may suggest that perceived cancer risks from hazardous waste sites are higher than they really are. For this reason, Gayer, Hamilton & Viscusi (2000) distinguish between the private values that residents place on risk reduction and those values that are expressed publicly in surveys. Indeed, by using market data instead of survey data, the authors are able to do their analysis with data that reveals the real preferences of the people. As a result, they also use a Bayesian learning process that is linked to a hedonic framework. In this case, the release of objective information lowers the perceived levels of risk.

2 Empirical research

2.1 General results

At the moment, several empirical applications of the hedonic price model have already been conducted, especially in the United States. Most of these studies try to monetize the harmful effects of living in the proximity of one or several landfills. Results of these studies differ with respect to the magnitude of the effect, but what is important is that the effects all point in the same direction, i.e. a reduction in value the closer the house is situated to the pollution source. Brisson and Pearce conducted a meta-analysis, using 13 hedonic price studies (mainly American) to measure the effects of living in the neighbourhood of a landfill or a hazardous waste site. Table 2 reports the results of the estimated willingness to pay function.

Table 2 Estimated willingness to pay

Distance from polluted site (in miles)	House price reduction (in %)
0	12.8%
1	9.0%
2	5.2%
3	1.4%
3.4	0%

Source: Brisson and Pearce (1995)

The regression analysis shows a declining effect with distance. The biggest effect, a house price reduction of 12%, can be found in the immediate surroundings of the pollution source. Then the influence fades away slowly until approximately 3.4 miles from the site. At that distance, the pollution risk is no longer incorporated in the housing prices.

2.2 Case study for Flanders

In the north-eastern part of Flanders, industrial zinc production already started in the second half of the 19th century. Around the site of an old zinc smelter, situated on the border of two communities, Overpelt-Lommel, serious land contamination, consisting of heavy metals, is a known problem. The population is well aware of the situation, all the more that government agencies distributed information about the pollution and issued restrictions on the use of vegetable gardens. An epidemiological prospective population study for the region concluded that 'even at low degree of environmental exposure, cadmium may promote skeletal demineralisation, which may lead to increased bone fragility and raised risk of fractures' (Staessen et al., 1999, p.1140).

The hedonic price analysis about the benefits of an eventual land reclamation started from data on cadmium contamination (mg / kg dry soil), represented with contours on a map of the area. Parallel with the contours indicating Cd concentrations of 12, 6 and 3 mg/kg, we designed contours indicating the distance from the 'core-pollution' (12 mg/kg Cd) with regular intervals of 500 meters. These areas are indicated as 'zones'. After this marking out, all sales of residential houses were registered over the period 1989-1998 within a distance of 2500 meters from the core pollution. For these sales information was available about localisation, sales price, size (small, medium-sized, large, residence) of the house, surface of the parcel, number of rooms, garages, etc., maintenance condition, and comfort class. We gave each house a code according to the distance (zone) and according to whether the house was situated inside or outside the centre of the communities.

The estimated hedonic price equation, withholding only the significant variables, looks like:

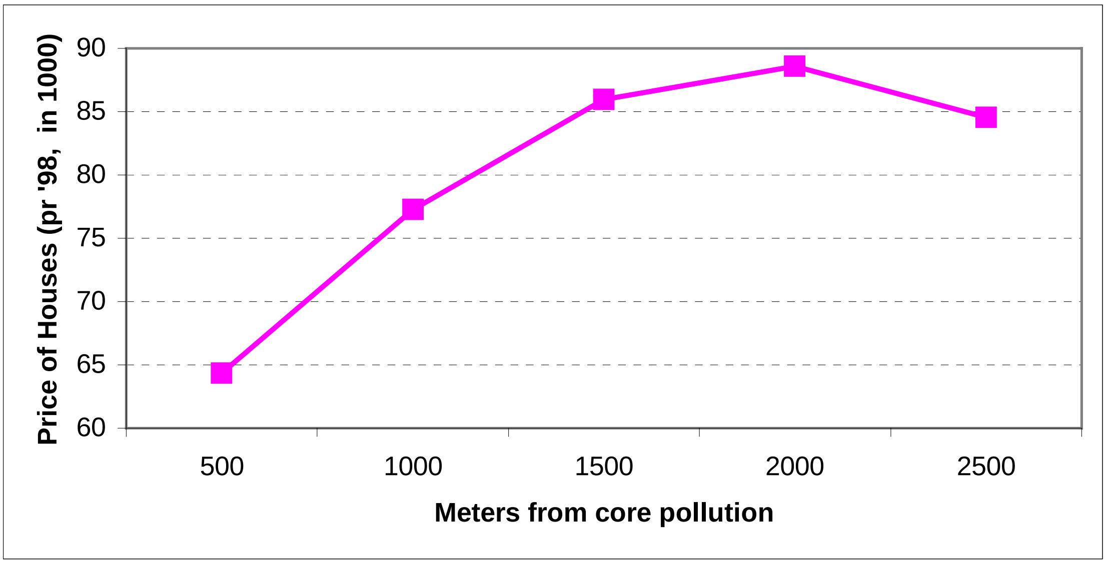
$$Log(PRICE_i) = B_0 + B_1*ZONE_i + B_2*(ZONE_i)^2 + B_3*HOUSECLASS_i + B_4*SURFACE_i + e_i \quad (1)$$

The independent variables are ZONE: the distance zone, HOUSECLASS: the size of the house, and SURFACE: the surface of the parcel. The log-quadratic specification allows for a degressive influence of the distance from the core pollution. To fix the idea, one can deduce the 'Marginal price of distance' (MPD) from the estimated values of the coefficients B_1 and B_2 as:

$$MPD = (B_1 + 2*B_2 * \text{Average distance}) * \text{Average sales price} \quad (2)$$

As a result we come to an estimated price of distance of € 4168 per 500 meters (prices of 1998), being 5.3% of the median sales price. Per zone of 500 meters further away from the polluted site, the real sales price for a comparable house increases with ca. 5%. This effect is observed until a distance of 2000 meters (see figure 1).

Fig. 1 Value of houses (€ 1.000) and distance from the polluted site (Overpelt-Lommel)

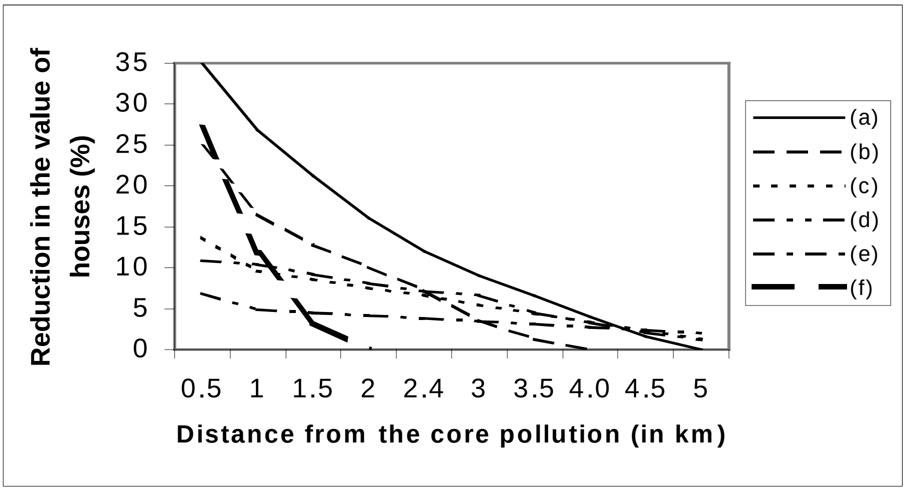


Source: Thewys et. al. (2000)

Applying these results on the number of houses (subdivided by size) in every zone, we arrive at an estimated loss of value in the range of € 20 – 23 million. This amount can be considered as an estimation, of the benefits of a clean up, being the removal of the loss of value of the real estate. It can be compared with the cost of different possible reclamation techniques. The benefit-cost ratio can be used in setting priorities in the governmental reclamation program.

The above-mentioned study of Thewys et al. (2000) clearly differs from other American studies (see figure 2). This shows the difficulty for European countries of relying on benefits transfer techniques (meta-analysis of American studies). Europe definitely needs its own valuation studies in order to assess and monetize the risks from soil contamination.

Fig. 2 Reduction in the value of real estate nearby polluted sites



Legend: (a) Hirshfeld (1992); (b) Baker (1982); (c) Kiel a.o. (1995); (d) Kohlhase (1991); (e) Brisson (1997); (f) Thewys a.o. (2000).

3 Conclusion

The hedonic pricing method is a good tool for measuring social benefits stemming from soil reclamation programs in polluted areas. Studies conducted in the United States, mainly from pollution arising from landfills or hazardous waste sites, indicate that the devaluation of housing prices diminishes with the distance. The gap between housing value before and after the contamination is the largest in the immediate surroundings of the pollution source. Transferring the results of these American studies to the European context is dangerous. Consumer behaviour and town and country planning are totally different. Even within Europe there are huge discrepancies between countries such that each country should conduct their own benefit analyses. This would give the most reliable results. However, it will take time and a lot of money to do so. But the growing concern for a clean environment makes it definitely worthwhile to conduct such studies, especially when the causality between health problems and a specific pollution source becomes more and more obvious. Once a country disposes of a number of benefit studies for some well-chosen polluted sites, they can make use of benefits transfer methods to gauge similar sites in a fast and reliable way. As mentioned above, a cost-benefit analysis can then be used to make a priority ranking on an economic basis. Until now, priority has been set with the principle of cost-effectiveness of remedial techniques for each separate site.

Finally, we want to pay attention to two important points about the application of the hedonic price method. First, it is absolutely necessary that the people living in the contaminated area are aware of the pollution. If there is no consciousness of what is going on, housing prices will not reflect the risks of living in the polluted property. Second, the link between the environmental good and the differentiated product (the house) may be weak. It can be difficult to disentangle what is really measured. Are we really measuring contamination effects or only the aesthetics of the neighbouring polluting factory? In this field, there is still a lot of research to do. The application of the hedonic price method should be conducted separately for people living in the neighbourhood of a polluting factory and for those living in the surroundings of a non-polluting company. Then, the results can be compared with each other. Nevertheless, it seems to be the case that the hedonic price method is a most promising one since it is not only based on the concept of 'willingness to pay' for a clean environment, but this willingness to pay is also revealed in real market behaviour.

4 Literature

Bartik T.J. (1988). Measuring the benefits of amenity improvements in hedonic price models. *Land Economics*, 64(2), pp. 72-83.

Benedetti M., Lavarone I. & Comba P. (2001). Cancer risk associated with residential proximity to industrial sites. *Archives of Environmental Health*, 56(4), pp. 342-349.

Brisson I. (1997). Assessing the 'Waste Hierarchy': a social cost-benefit analysis of MSW management in the European Union. *SØM publication* Copenhagen, 19, pp 46.

Dolk H., Vrijheid M., Armstrong B., Abramsky L., Bianchi F., Garne E., Nelen V., Robert E., Scott J.E.S., Stone D. & Tenconi R. (1998). Risk of congenital anomalies near hazardous-waste landfill sites in Europe: the EUROHAZCON study. *The Lancet*, 352, pp. 423-427.

Ferguson C., Darmendrail D., Freier K., Jensen B.K., Jensen J., Kasamas H., Urzelai A., & Vegter J. (1998). *Risk assessment for contaminated sites in Europe. Volume 1. Scientific Basis.* LQM Press, Nottingham.

Gayer T., Hamilton J.T. & Viscusi W.K. (2000). Private values of risk tradeoffs at superfund sites: housing market evidence on learning about risk. *The Review of Economics and Statistics*, 82(3), pp. 439-451.

Hamilton & Viscusi (1999). How costly is "clean" ? An analysis of the benefits and costs of superfund sites remediations. *Journal of Policy Analysis and Management*, 18(1), pp. 2-27.

Kiel, K., Measuring the impact of the discovery and cleaning of identified hazardous waste sites on house values. *Land economics*, Vol.71, no.4, 1995, pp.428-35.

Kohlhase, J., The impact of toxic waste sites on housing values. *Journal of Urban Economics*, Vol.30, 1991, pp.1-26.

Lafère J. & L. Hens (2002). Gezondheidsrisico's van wonen in de omgeving van een stortplaats of verbrandingsoven. *Leefmilieu*, 3, mei-juni, pp. 71-76.

McCluskey J. & G. Rausser (2001). Estimation of perceived risk and its effect on property values. *Land economics*, Feb. 2001, pp. 42-55.

Mundy B. (1992). The impact of hazardous materials on property value. *The Appraisal Journal*, April 1992, pp. 155-62.
Rosen S. (1974). Hedonic prices and implicit markets: product differentiation in pure competition. *Journal of Political Economy*, 82, pp. 34-55.
Staessen J., H. Roels, D. Emelianov, T. Kuznetsova, L. Thijs, J. Vangronsveld & R. Fagard (1999). Environmental exposure to cadmium, forearm bone density, and risk of fractures: prospective population study. *The Lancet*, 353, April 3, pp. 1140-44.
Thayer, Albers & Rahmatian (1992). The benefits of reducing exposure to waste disposal sites: a hedonic housing value approach. *The Journal of Real Estate Research*, 7(3), pp. 265-82.
Thewys T. (1998). Kosten-batenanalyse en kosteneffectiviteitsanalyse in het kader van bodemsanering. *Energie en Milieu*, 3, pp. 116-119.
Thewys, T., Draye A-M. & Kwanten A. (2000). Economische baten van bodemsanering (Economic benefits of soil reclamation). Studie in opdracht van de Openbare Vlaamse Afvalstoffenmaatschappij, OVAM, Mechelen, 75p.
Thewys T. & Clauw F. (2002). Bodemsanering in een stakeholdersperspectief. Het meten van milieubaten via de hedonistische prijsmethode (Soil remediation from the perspective of the stakeholder. The measurement of environmental benefits via the hedonic price method). Congresboek VWEC, pp. 899-923.
Viscusi W.K. & Hamilton J.T. (1999). Are risk regulators rational? Evidence from hazardous waste cleanup decisions. *The American Economic Review*, 89 (4), pp. 1010-1025.
Vrijheid M., Dolk H., Armstrong B., Abramsky L., Bianchi F., Fazarinc I., Garne E., Ide R., Nelen V. Robert E. Scott J., Stone D. & Tenconi R. (2002). Chromosomal congenital anomalies and the residence near hazardous waste landfill sites. *The Lancet*, 359, Jan. 26, pp.320-22.

OIL REFINERY DECOMMISSIONING. RISK BASED REMEDIATION CRITERIA

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ABSTRACT

The A/S Norske Shell Oil Refinery at Sola, near the town of Stavanger in south-western Norway, was closed down after 32 years of operation. The ground of the 60 hectares refinery area on the North Sea shore had become contaminated by both crude oil and a range of refined petroleum hydrocarbons and some landfilled refinery waste. Norske Shell is obliged to remediate the site to make it suitable for future industrial and commercial uses use by July 2003.

This paper describes the environmental risk assessments that were conducted to establish the site specific remediation criteria, and how some of these criteria have been verified during the remediation process. The remediation targets are based on an assessment of present and potential future conflicts and associated risks to human health and the environment.

THE SHELL SOLA REFINERY DECOMMISSIONING PROJECT

The Shell Oil Refinery at Sola was a fairly standard small refinery with a capacity to process 2.6 mill tonnes of crude oil per year. It was closed down in April 2000. The landholding was sold in 2002 to be redeveloped by the new owners for other industrial and commercial uses. Norske Shell is remediating the site to make it suitable for the future uses by July 2003. As the exact future use is unknown, and because redevelopment will take many years, the entire renovated site must satisfy requirements to both industrial and recreational uses.

The Shell Sola Refinery decommissioning comprises two projects regarding ground contamination; one concerning the refinery ground and groundwater in general and one for the crude oil caverns. This paper is limited to the first project. The main participants have been:

- IWACO BV (Netherlands) with sub-contractor Norconsult AS (Norway); Main environmental site investigations (Phase II ESA), environmental risk assessment, evaluation of remediation needs.
- NIVA (Norwegian Institute for Water Research); Marine investigations
- NOTEBY AS; Environmental advisor to Shell; Phase I ESA, management/coordination of risk assessments, permitting and regulatory matters, preparation of tender documents, works supervision, supplementary ESA II investigations, marine environmental surveys (with NIVA).
- T. Stangeland Maskin AS, Contractor for the remediation works, with subcontractors SITA Remediation and DNV

The initial investigations started in August 1999 and the application for regulatory approval of the proposed remediation was submitted in March 2001. The approval was given in January 2002. The soil and groundwater remediation contractor mobilised in December 2001 after the above-ground demolition works had been completed. By July 2003 approximately 500,000 tons of soil have to be processed, out of which 250,000 tons are expected to need treatment to remove contaminants. The treatment takes place on site by soil washing and composting, supplemented by a thermal process.

A paper submitted by the remediation contractor describes the actual remediation works.

SITE DESCRIPTION

The refinery site is a rocky peninsula facing the North Sea to the north and west, and forming the western shore of the bay and harbour Risavika. Average annual precipitation is approx. 1000 mm and the average monthly temperature varies from 14 ^{o}C in July/August to 0.4 ^{o}C in February.

The refinery had a deep-water jetty, storage facilities for 200,000 tonnes of crude oil in one conventional aboveground tank and four underground rock caverns, and tank storage for 220,000 tonnes of products. Product export was either by ship from the refinery jetty or by pipeline to a product depot 2.7 km away from the refinery.

The ground is bedrock, blasted rock fill and local sand, silt and clay. The total property area is approximately 100 hectares, of which 60 hectares made up the refinery area proper ("on-site" area).

Figure 1. The former Shell Sola Refinery

The process area, most tankfarms, pipelines, and sludge / waste handling areas are situated on native soil and fill of rock and imported sand in a depression between rock ridges.

Groundwater level is normally 1-2 m below grade in the process area and tankfarms. The groundwater gradient falls towards the sea from a divide in the vicinity of the process area. The main migration path follows the soil filled depression of the main pipeline past the tankfarms towards the jetty. Some other possible migration directions are partly through off site areas.

A buried concrete wall in the ground along the eastern harbour area intercept and contain any free phase oil migration in this direction. Another wall in the ground contained product migration towards the adjacent properties in the south.

Roads and process areas were paved by asphalt and concrete/concrete paving stones. All tankfarms were fully bunded with containment walls/embankments. Four of the eight farms were paved with asphalt, the remaining having sand and gravel fill surfaces. Virtually all process pipework was above ground, with no containment. Drainage systems were typically 1 – 2 m underground.

The adjacent land areas to the south and east have a mixture of commercial and agricultural uses. Residential rural housing is located within a few hundred metres south of the site. The shoreline to the south of the refinery site is a protected nature area.

CONTAMINATION STATUS AT THE TIME OF CLOSURE

The refinery site had become contaminated by both crude oil and a range of refined petroleum hydrocarbon products, and some land filled refinery waste including catalyst and sludge.

Soil, rock and groundwater

The ESA II investigations concluded that oil contamination had impacted the soils to below the groundwater level and consequently the groundwater and some bedrock, whereas the metals contamination seemed limited to some of the surface soils. Groundwater was only slightly and locally impacted by metals. MTBE was found in the groundwater at one tank locality, and TEL and lead was proven in the soil at the former area for addition of organic lead to the petrol (OCTEL-area).

Table 1. Summary Phase II ESA results

Main polluted areas	Polluting chemical	
Main process area, tankfarms and central pipe track, sludgebasin area, flare area, fill area for construction waste, OCTEL, Cavern tops, Contractors yard.	Oil:	Soil: TPH from 2.000 to 10.000 mg / kg Groundwater: TPH average from 1 to 100 mg/l, partly with free product phase
Note: Soils with metals contamination mainly in tankfarms and waste fill area with catalyst and sludge.	Heavy metals:	Soil: As, Cr, Cu, Pb (max 1200 mg/kg), Zn Groundwater: As

Oil = Common term for all oil related hydrocarbons incl. BTEX and PAH

Contaminant migration to marine areas

The highest concentrations of pollutants in the groundwater near the discharge areas to the marine environment were found in the northeast / jetty area (Risavika harbour) and in the northwest at the sludge basin area. Simple mass balance calculations indicated a groundwater discharge of dissolved petroleum hydrocarbons to the Risavika in the northeast of 19 kg/yr, or roughly 0.3 % of the permitted discharge from the former refinery operations.

Marine areas

The harbour area sediments had been monitored during the refinery operations. Those results were supplemented by environmental baseline studies in 2000/2001. There was no evidence of active migration of heavy metals, petroleum hydrocarbons or PAHs of environmental concern to the marine environment. The only exception was oil components from the filled ground near the sludge basins, shown by hydrocarbon accumulation in transplanted mussels. Otherwise, the sea area to the west of the refinery was classified as none- or slightly impacted by contaminants. The harbour to the east had slightly to moderately impacted water, whereas the sediments near the refinery discharge pipe to the same harbour were moderately to markedly impacted by PAH and heavy oil components.

ENVIRONMENTAL TARGETS. FUTURE LAND USE

The assessment of site-specific remediation targets was based on the following primary environmental targets for future land use.

- There shall be no unacceptable risk to human health or the environment from contaminated ground (soil. groundwater and bedrock)
- There shall be no unacceptable migration of contaminants hazardous to human health or the environment
- There shall be no adverse effect on the marine environment beyond that of the established background level.
- There shall be no unacceptable odour from the ground

ENVIRONMENTAL RISK ASSESSMENT. METHODOLOGY

The risk based environmental site assessment had the following primary goals:

- To derive land use differentiated soil acceptance / remediation criteria based on actual exposure risks and soil properties, and then use these values to evaluate the need for remediation
- To present a groundwater remediation strategy, including evaluation of contamination migration from groundwater to marine receptors and between areas of different land use.

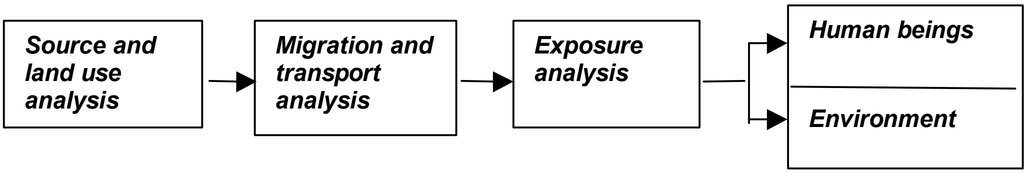
The assessment was mainly based on the guidelines of the Norwegian Pollution Control Authority (SFT); report 99:06, “Guidelines on risk assessment of contaminated sites”.

The Norwegian risk assessment system for contaminated sites

The Norwegian guidelines for management of contaminated sites give a national norm for the content of potential contaminants in soil for most sensitive land use (SFT norm), assuming seven possible conflicts and contaminant migration paths. Evaluation of groundwater contamination is based on the national drinking water guidelines and ecotoxicological evaluations of recipients.

The guidelines allow a site specific assessment of remediation target values for sites with other land use than the most sensitive, or whenever the actual physical migration conditions differ from the default values assumed to derive the norm. The conflicts and risks to be considered depend on the site, but are generally related to human health and safety, and ecological life, as shown by Fig 2. The site owner may also consider economic risks like present and future property values.

Figure 2. Assessments to be carried out for a site specific risk assessment



When calculating the total human exposure to a contaminant, the additive effects of the various possible exposures are assumed. In the case of the SFT norm values, the total acceptable exposure concentration (C_{he}) for each contaminant is calculated from de-fault reference soil concentration values for each of the seven exposure pathways considered by the norm, as:

$$C_{he} = \frac{1}{1/C_{is} + 1/C_{du} + 1/C_{id} + 1/C_{iv} + 1/C_{gw} + 1/C_{ig} + 1/C_{if}}$$

where the reference soil concentration values are for:

C_{is} = ingestion of soil or dust
C_{du} = dermal contact to soil or dust
C_{id} = inhalation of dust
C_{iv} = inhalation of soil vapour. (through indoor air from housing at the contaminated site)
C_{iw} = intake of drinking water (.from a groundwater well located at the contaminated site)
C_{ig} = consumption of vegetables and crops (grown at the contaminated site)
C_{if} = consumption of fish or shellfish (from a nearby recipient contaminated by groundwater)

For site-specific assessments, only the relevant exposure pathways and conditions are considered.

The results of the risk assessment and the acceptance / remediation target values to be adopted are to be approved by the SFT. Adoption of other acceptance criteria than the national norm for most sensitive land use will in most cases trigger a special listing of the site. A new assessment will then be required prior to any future change in the use of the subject land.

Site specific adaptations

Evaluation of chemicals of concern. Petroleum hydrocarbons

In the case of oil products, the Norwegian reference soil concentration values are based on the BTEX components and six fractionated groups of aliphatic hydrocarbons. The fractions and their assigned toxic properties are as identified by the Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG). However, the norm values are expressed by only three fractionated groups, see Table 3.

Due to the complex hydrocarbon contamination at the Shell Sola site, the SFT requested the development of additional toxicity acceptance criteria for other aromatic hydrocarbons than the BTEX-components. This was done for six fractions in accordance with the TPHCWG recommendations.

Except for phenol, all other chemicals of concern found to be present on site were included in the Norwegian guidelines.

Exposure conditions and soil parameters
Migration calculations were based on the local soil properties and assuming a future maximum groundwater level of 0,5 m below grade / foundation level.

At the time of the assessment the future use of the site was uncertain and a series of alternatives were considered by the exposure analyses. Table 2 gives the assumed exposure conditions.

Table 2. Exposure conditions relative to type of land use

Land use	Exposure [1]	Duration of exposure	Reference
Residential Upper 1 m of soil	Ingestion of soil Dermal exposure Inhalation of dust Inhalation of soil vapours Consumption of vegetables	365 d / 8 h. Adult and Child (A, C) 365 d / 8 h (A, C) 365 d / 24 h (A, C) 365 d / 24 h (A, C) 30 % of total vegetable consumption	SFT default values
Residential > 1m below surface	Inhalation of soil vapours	Adult and Child: 365 d / 24 h	SFT default values
Industrial area Open surface	Ingestion of soil Dermal exposure Inhalation of dust	Adult: 200 d @ 10 h	Noteby, 1999
Industrial area Paved surfaces [2]	Inhalation of soil vapours	Adult: 200 d @ 10 h	Noteby, 1999
Recreational areas	Ingestion of soil Dermal exposure Inhalation of dust	Adult: 156 d @ 3 h Child: 260 d @ 3 h	Noteby, 1999
Public areas	Ingestion of soil Dermal exposure Inhalation of dust Inhalation of soil vapours	Adult and Child: 220 d @ 8 h	Noteby, 1999

[1] Exposure through consumption of drinking water and fish are not relevant, and are therefore not included.
[2] Land use where gasses can volatize into buildings, i.e.; soil beneath buildings and immediately adjacent paved surfaces such as parking lots, etc.

The groundwater on site is not suitable for drinking water extraction due to hydrogeological reasons.

The possible exposure through consumption of fish impacted by migration of chemicals from the site was excluded, based on a special assessment of the possible marine impacts. These were found to be negligible.

Groundwater and marine life
The groundwater remediation strategy at Sola comprises two parts:
- Preliminary remedial actions to remove free phase product (and soil remediation)
- Long term remediation based on monitored natural attenuation (MNA) of contaminants

For the MNA strategy to be successful, the groundwater quality must satisfy the following targets:
- Contaminant concentrations must not cause unacceptable emissions of toxic or odorous gases
- Contaminant concentrations must not be toxic to micro-organisms necessary for attenuation and bio-degradation processes
- Contaminant concentrations must not cause unacceptable migration to marine receptor
- Contaminant concentrations must not cause unacceptable migration to other land use areas that have more stringent groundwater criteria.

The Norwegian system does not include methods for calculation of emissions of volatiles from groundwater. Such calculations were carried out by the Canadian consultants Jacques Whitford Environment Ltd, (JWEL) using the Atlantic Piri RBCA toolkit and appropriate site-specific parameters.

Aquateam AS, Norway conducted a literature search to develop criteria for acceptable contaminant concentrations (LOEC / NOEC) with respect to bacterial life to ensure natural attenuation.

Aquateam also proposed the quality criteria for groundwater discharging to the marine areas, based on PNEC-values for marine life and a modest contaminant dilution factor in the shore zone.

APPROVED RISK BASED REMEDIATION CRITERIA

Soil

The site zoning was decided to be for industry and recreation. The final remediation target values are therefore a combination of the risk based values for these land use categories as shown by the last column in the table below.

Table 3. Risk based soil remediation target values (mg/kg dry matter)

Chemical	SFT Norm Most sensitive land use	Industry		Recreation	Combined Industry and Recreation
		Open surfaces	Paved / built surfaces		
As	2	8.6	1	12.2	**8.6**
Pb	60	1800	1	350	**350**
Cd	3	300	1	140	**140**
Hg	1	500	3.1	120	**3.1**
Cu	100[3]	2	1	2	**2**
Zn	100[3]	2	1	2	**2**
Cr (total)	25	32	1	82.1	**32**
Ni	50	679	1	382	**382**
PAH total	2	11	2868	18	**11**
Benzo(a)pyren	0.1	0.67	179	1.1	**0.67**
PCB CAS1336-36-3	0.01	1.4	132	2.0	**1.4**
Benzene	0.005	312	0.05[4]	474	**0.05[4]**
Toluene	0.5	2	1.4	2	**1.4**
Ethylbenzene	0.5	2	1.8	2	**1.8**
Xylene	0.5	2	2.7	2	**2.7**
Aromatics >C07-C08	None	2	15	2	**15**
Aromatics >C08-C10	None	8400	20	2600	**20**
Aromatics >C10-C12	None	8400	110	2600	**110**
Aromatics >C12-C16	None	8400	570	2600	**570**
Aromatics >C16-C21	None	6300	4400	2000	**2000**
Aromatics >C21-C35	None	6300	2	2000	**2000**
Aliphatics > C5-C10	7	2	24	2	**24**
Aliphatics >C10-C12	30	2	117	2	**117**
Aliphatics >C12-C16	100[3]	2	561	2	**561**
Aliphatics >C16–C35		2	2	2	**2**
MTBE	2	2	166	2	**166**
Tetraethyl lead	0.001	0.075	0.003	0.019	**0.003**
1,2-dibromo methane	0.004	0.099	0.004	0.15	**0.004**
1,2-dikloro ethane	0.003	810	0.008	1267	**0.008**

Notes:
1) non-volatiles have no value for vapour inhalation
2) values > 10.000 mg/kg dry matter
3) based on ecotoxicological values
4) Value for detection limit, in line with international screening values for contaminated soil.

- **These target values are valid for soil to a depth of 1.5 m from grade or down to groundwater level where that is deeper than 1.5 m.**
- **Soil remediation below 1.5 m depth or the groundwater level may be limited to removal of any mobile oil contamination that may cause free phase product formation on the groundwater.**
- **Soil down to 0.5 m depth shall meet additional ecological requirements.**

The site specific remediation criteria or target levels (SSTL) for petroleum hydrocarbons are determined by the potential conflict of inhalation of vapour penetrating into future buildings.

The SSTL values cover the following aspects related to human health:

- Toxicity, the fractionated limits for 10 hydrocarbon fractions. (SSTL-values)
- Cancerous properties, requirements to contents of benzene and PAH

As the fractionated petroleum hydrocarbon criteria do not protect against the cancerous properties of the oil product constituents, they should always be used in combination with the separate criteria for benzene and PAH.

Groundwater

After removal of all free phase products from the groundwater and completed soil remediation, the groundwater shall meet the following criteria with respect to petroleum hydrocarbons:

Table 4. Risk based groundwater criteria (mg/l)

Chemical	Criteria for industrial land use	Controlling conflict
Benzene	3,1	Vapour to buildings
Toluene	29	Organisms, LOEC / NOEC values
Ethylbensene	12	
Xylene	70	
TPH, ie; petroleum hydrocarbons excl of BTEX	100	
PAH	> 20	

Monitoring program and targets for the further natural attenuation of groundwater contaminants, including criteria for need of corrective actions shall be decided based on the verified conditions after completion of the soil remediation works.

Marine environment

Future groundwater discharges to the marine areas shall not exceed values that may have adverse effects on marine life. Drinking water criteria were adopted for the content of heavy metals and accepted PNEC-values are used for organic contaminants. These values are much lower than the criteria for the contaminant content in groundwater in general. A dilution factor of 10 has been assumed for verification of satisfactory groundwater quality in near-shore observation wells, as shown by table 5. Additional dilution in the ground between the observation well and the sea is also included, where relevant.

Table 5. Groundwater criteria for discharge areas to marine environment (mg/l)

Chemical	**Groundwater conc.** (Incl. dilution factor of 10)
Sum BTEX	0.170
TPH > C6-C12	0.040
TPH > C12-C35	10
PAH sum 16	0.023

Ecotoxicology

Ecotox considerations are not included in the shown Combined Industry / Recreation values. However, ecotox considerations were included by additional requirements to surface soils.

Furthermore, SFT requested documentation of the ecotoxicological properties of contaminated soils that met the site specific acceptance criteria without treatment, and also of treated soils to be used in future surfaces. The reason for this was to investigate possible unacceptable soil properties not disclosed by the criteria based on chemical analytical test results. A test program including nitrification, soil living vertebrates and plants has therefore been instigated.

PRACTICAL APPLICATION OF REMEDIATION CRITERIA FOR HYDROCARBONS

In the case of petroleum hydrocarbons, each remediation target value (SSTL) defines the concentration above which the content of that hydrocarbon fraction in the soil constitute an unacceptable threat to human health. The fractionated SSTL values are not additive, as each value has been worked out under the assumption that no other hydrocarbon fractions are present.

However, the soil contamination consists of a mixture of several hydrocarbon fractions. To evaluate remediation criteria for such mixtures, the mass fractions of the contaminants present on the site have to be considered. The "inverse weighted average" method as proposed by the TPHCWG is used for these calculations.

The total petroleum hydrocarbon criterion $SSTL_{TPH}$ defined by this method is: $\mathbf{SSTL_{TPH} = C_{tot} / HI}$

where: C_{tot} = total concentration of all fractions

HI = Hazard Index = $\sum_{i=1}^{n} HQ_i = \sum_{i=1}^{n} Min\left[\left(\frac{c_i}{SSTL_i}\right);\left(\frac{C_{sati}}{SSTL_i}\right)\right]$

HQ = Hazard Quotient, for each TPH fraction

c_i = concentration of fraction "i"

$SSTL_i$ = the site specific target level for fraction "i"

C_{sati} = upper-bound value, the saturation concentration for the soil source area for the TPH fraction "i".

C_{sat} is the contaminant concentration in soil at which absorptive limits of soil particles, solubility limits of soil pore water, and saturation limits of soil pore air are reached. For most petroleum hydrocarbons, C_{sat} is much lower than the concentration of hydrocarbons at which mobile free product or separate phase would be present.

Because the formula for the $SSTL_{TPH}$ criterion include the mass-fraction properties of the contaminant product, one single criterion for the Sola refinery site with a variety of products, would be very conservative and unpractical.

Based on the ESA II results, calculations showed that remediation would be required for total concentrations varying between 100 and > 2.500 mg/kg, depending on the actual hydrocarbon product mixture.

But the use of the full detailed criteria would require a comprehensive program of chemical analyses and calculations for the management of the remediation works, which would also be costly and impractical.

Based on evaluation of the results of the Phase II ESA investigations and some supplementary analyses of all the defined TPH fractions, if was found that a simplified fractionated approach based on the following parameters would be sufficiently accurate for the Shell Sola site:

Table 6. Recommended simplified screening levels for TPH (sum of aliphatic and aromatic components). Human health considerations

TPH fraction	Simplified SSTL Industrial closed (mg/kg) (from aliphatic fraction values)	Site–specific C_{sat} values mg/kg (from aromatic values)
>C6-C10	24	1237
>C10-C12	117	565
>C12-C16	561	262
>C16-C35	5000 [1]	92

Note: 1) Not a risk based value, but an upper limit imposed by the SFT

Any soil with a hazard index HI > 1 must be treated. The calculations do not have to be carried further than to the HI step to determine the need for remediation. In addition the soil has to satisfy the benzene and PAH criteria shown by table 3.

RESULTS FROM THE REMEDIATION WORKS

During the practical remediation works, one sample pr every 100 m^3 of soil < 50 mm is being analysed chemically by method GC/FID to evaluate the need for treatment with respect to oil components. Each 100 m^3 of treated soil is also being tested. The analyses comprises the BTEX components, the four TPH fractions given by table 6 and PAH. A simple PC-program calculates the HI-value of each sample

Evaluation of the use of simplified criteria

The initial evaluation of the minimum number of hydrocarbon fractions necessary to define satisfactory soil quality with respect to human health indicated that:

- The evaluation based on 3 TPH values (>C6-C10, >C10-C12, >C12-C35) detected all samples with an HI > 1, and thus in need of remediation, but tended to underestimate the HI value and would thus possibly "approve" unacceptable soil
- The chosen evaluation based on 4 TPH fractions (see Table 6) gave the best agreement with the evaluation based on both aliphatic and aromatic fractions, and seemed to err on the safe side

This has been studied by some further testing during the remediation, mostly on treated soils and spoils with a hydrocarbon content near the HI = 1 concentrations.

Table 7. Evaluation of the number of fractions required to calculate the Hazard Index (HI) Average results

TPH mg/kg	Sum TPH from 8 aromatic / aliphatic fractions	% content of aromatic fractions	HI-3	HI-4	HI-8 [1]
1194	1424	15	1.84	2.19	1.25

Note: 1) HI-8 = Aliphatics: >C5-C10, >C10-C12, >C12-C16, >C16-C35. Aromatics: C8-C10, >C10-C12, >C12-C16, >C16-C35

The results so far seem to confirm the initial evaluation.

In only one out of the 14 tests did the simplified HI-4 analyses adopted by the project underestimate the HI and approve a soil found to be unacceptable (marginally) by the HI-8 method. In that case the content of heavy aromatics constituted approximately 30 % of the total hydrocarbon content, which is untypical for this samples site. In one other case, the HI-4 approach caused disapproval of an acceptable soil.

The main reason why the HI-4 method gives less accurate HI values compared to the HI-3 method (see table 7) is the use of C_{sat} values for aromatic fractions, which are 4 to 7 times higher than the C_{sat} values for aliphatic hydrocarbons of the same fraction interval. For the investigated samples with a content of aromatics mostly varying between 10 and 20 %, use of aliphatic C_{sat} values would have given better accuracy for the simplified calculations, but with a risk of not detecting the few borderline samples with untypically high aromatics content. Optimum choice of C_{sat} value for use with the HI-4 method could with advantage have been evaluated for some of the sub-areas with relatively uniform contamination properties, to improve the accuracy of the method.

Ecotoxicological testing

The ecotox verification program has been based on a test packet comprising the following properties:

- micro-organisms, soil nitrification,
- plants, the seed emergence (sprouting) and growth of two species
- vertebrates, collembola survival and reproduction
- microtox testing on eluate from leaching tests on treated soils, limited program

The results by January 2003 are summarised in the table below. The performance of the various samples is compared to that of local uncontaminated reference soils. The clean local soils have similar qualities as a standard Norwegian agricultural soil, except for a somewhat reduced growth capacity for plants. Treated soils with < 50 % impeded ecotoxicological performance when compared to the local reference soils are permitted used as ecological surface soils. This is because the reduced performance of the treated soils mainly appear to be caused by a lack of nutrition and organic matter and some pH effects, which will all be improved with time through natural processes. All the tested soil samples had acceptable quality for use on the site, based on the results of the chemical analyses. None of the treated soils yielded toxic leachate in the supplementary microtox tests.

Table 8. Ecotoxicological laboratory testing. Summary of results by January 2003

Soil type	Vertebrates	Plants	Micro-organisms nitrification	Remarks / Conclusion
Soils that meet the site specific analytical criteria without treatment	As for reference soil	Sprouting as for reference soil. Growth from 0 to 47 % reduction	From 0 to 20 % reduction	Acceptable surface soil. Sample with reduced properties had high pH
Soil treated by washing	Reproduction reduced by 0 to 60 %	Sprouting reduced by 0 to 65 %. Growth reduced by 30 to 60 %	As for reference soil	Soil treated by washing will be acceptable surface soil when fortified by nutrition and organic matter
Soil treated by washing, fortified by nutrients	None to slight reduction in reproduction	Sprouting reduced by 0 to 65 % Growth as for ref. soil	As for reference soil	
Soil from thermal treatment	Reproduction reduced by > 80 %	Growth reduced by 20 to 40 %	Reduced by ca 20 %	Not suitable in upper 0.5 m. Will become acceptable with time, due to natural processes, as shown by the test with pH adjustment.
Soil from thermal treatment, pH adjusted and desalted	As for reference soil	As for reference soil	As for reference soil	
From bio-treatment	As for reference soil	Improved growth	As for reference soil	Acceptable surface soil

CONCLUSIONS

- The environmental risk based approach resulted in efficient and cost effective strategies regarding groundwater remediation and measures to protect the marine areas
- The fractionated criteria for acceptable content of petroleum hydrocarbons in soils with respect to human health, gave a more accurate evaluation of the remediation needs than the standard Norwegian risk based method. This was important for a site with considerable variations in the contaminant product composition and concentrations.
- Full use of all the 13 fractions according to the TPHCWG method, or the reduced packet of 8 fractions tried in this project proved impractical. The main reason for this being the extra time required for the comprehensive fractionated analyses. Speedy results from the chemical testing laboratory was a key issue to avoid delays in the remediation works
- The simplified approach adopted by the Shell Sola project seems on the safe side and satisfactory with regards to limiting the amount of soils needing treatment. This is because the oil content of most of the contaminated soils have been well above the site specific accept criteria, and because the treatment methods used resulted in remediated soils with oil content well below the criteria
- Use of the full 13 (or 8) fraction system could possibly have resulted in a more accurate and cost saving evaluation of borderline soils and assisted the management of biological treatment processes.

REFERENCES

Norwegian State Pollution Control Authority (SFT): *Guidelines on risk assessment of contaminated sites. SFT report 99:06*. TA-1691.

Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG): *Volume 5; Human Health Risk-Based Evaluation of Petroleum Release Sites: Implementing the Working Group Approach*, Amherst Scientific Publishers, June 1999.

IWACO/Norconsult. *Risk Based Environmental Site Assessment (RB ESA II) for Soil and Groundwater – Sola Refinery*. January 2001

Atlantic PIRI Committee. *Risk-based Corrective Action (RBCA) Reference Documentation for Petroleum Impacted Sites in Atlantic Canada*, April 1999.

EVALUATION OF THE ENVIRONMENTAL IMPACT OF LIVE FIRING TRAINING AT CANADIAN FORCE BASE SHILO

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Abstract

Troop readiness involves the live fire training with various types of ammunitions. An important portion of the Canadian ammunition stockpile is used in our own Country in training exercises. This operational activity is critical to insure that our troops are always in a readiness state to take action in any potential international conflicts or peace missions. It is imperative to sustain this activity by insuring that its environmental impact is kept at the lowest as possible. By better understanding the impacts of each type of live firing activity, the department of National Defence (DND) will be able to mitigate potential adverse impacts by changing the practices to minimize the adverse impacts.

Following the German Army Training Establishment Shilo (GATES) closure at the Canadian Force Base Shilo (CFB Shilo, Manitoba) in Sept 2000, Defence Research and Development Canada-Valcartier (DRDC-Val) was tasked to conduct an environmental assessment of past training activities. This study was achieved to determine their impacts on soils, as well as sub-surface soils, surface water and groundwater in the training areas. The ultimate goal of this study was to globally assess the potential contamination related to explosives and heavy metals and propose mitigation techniques. Such an assessment requires an appropriate definition and understanding of the hydrogeological context of the site. CFB Shilo is mainly composed of five battle runs, one grenade range, three riffle and one anti-tank ranges. Soils, subsurface soils and groundwater samples were collected across all the training areas and battle runs according to the sampling procedure described in this paper. During phase I performed in Sept 2000, three battle runs were sampled for energetic materials, metals, Volatile Organic Compounds (VOCs) and petroleum products contamination to measure the impacts on soils, as well as sub-surface soils, surface water and groundwater in the training areas. Explosives, radioactive thorium (^{232}Th) coming from MILAN missile firing, petroleum products and heavy metals analyses revealed no major problems related to environmental contamination. However some trends were observed and thorium analyses revealed a localized impact close to the targets both in surface soils and in groundwater. It was recommended that MILAN missiles no longer be fired at the site.

During phase II performed in October 2001, the remaining two battleruns, riffle, grenade and anti-tank ranges were sampled according to procedures described in this paper. Soils, subsurface soils, biomass and groundwater samples were collected across all these training areas. Since some trends were encountered in phase I around target areas, more sampling including biomass samples was achieved. More background samples were also collected to evaluate the anthropogenic contribution. Explosives, ^{232}Th and heavy metals analyses revealed no major problems in battleruns related to environmental contamination. Thorium analyses revealed a localized impact close to the targets both in surface soils and in groundwater. The contamination by this chemical is not fully understood and more analyses will be done at the end of the summer 2002 to establish if the concentrations in groundwater are increasing or decreasing. Nevertheless, the concentrations in thorium do not represent a threat being 10 times below the Canadian Council of Ministers of Environment (CCME) criteria. High levels of metals were found in soils and groundwater both in riffle ranges and in the grenade range. Energetic materials and metals

contamination in soils and groundwater was found in grenade range. This paper describes the entire study including the approach, the strategy of sampling, the description of the hydrogeological context and, the analysis of more than five thousand parameters.

Introduction

Energetic materials are the main components of gunpowder, explosive warheads and solid rocket propellants and, therefore, can be found in war zones, training ranges or on industrial production sites. During this decade, many needs have already emerged related to the identification, quantification, delimitation and elimination of energetic contaminants dispersed by munitions, or present in explosives dumps, trials or destruction fields, firing areas and production sites [Refs. 1-21]. Many Canadian Forces sites used as impact areas, training ranges, demolition and open burning/open detonation (OB/OD) ranges, which were used to destroy out-of- specification materials, were highly suspected of being contaminated with energetic substances as described in the literature [Refs 1-10]. To evaluate the contamination of DND sites, sampling and characterization of various ranges was performed over the last ten years. A protocol describing the different methods of sampling and the analytical chemistry was developed [Ref. 11]. This protocol was recently updated in collaboration with CRREL and is presently being reviewed under the auspices of the Technical Cooperation Program (TTCP) by the member nations in a key technical area (KTA 4-28) [Ref. 12]. Research results to date have demonstrated that explosives are not common contaminants, since they exhibit limited aqueous solubility and are dispersed in a heterogeneous pattern of contamination. In the United States, a lot of efforts have been made to develop analytical chemistry, to establish the best sampling procedure and understand the complex fate of explosives in the environment [Refs. 4-8, 13-21].

CFB Shilo training area was selected to conduct the first R&D efforts to assess the environmental aspects of live firing activities since German troops stopped training aty this site in September 2000. The ultimate goal of this sampling campaign was to assess global contamination related to explosives, heavy metals and to radioactive ^{232}Th contamination. This information was used to determine Germany's share of any clean up and remediation costs, when required. This assessment required an appropriate definition and understanding of the hydrogeological context of the site, the Shilo base being located on a major aquifer that is heavily used for crop irrigation. Therefore, ensuring that no contamination migrated off site was critical.

This assessment addressed four areas of concern. The contamination patterns of surface soils around targets and in the battleruns were evaluated. The unconfined aquifer underlying the training area (hydrostratigraphy, hydraulic conductivity, groundwater flow direction, etc.) and groundwater quality were characterized. The extent of biomass contamination in the worst-case scenario locations was assessed, and, finally, the surface water quality was evaluated. In previous DRDC-Val studies, both energetic materials and metals contaminated surface soils were found in training ranges [Refs. 1,2,9-10]. Characterizing the groundwater quality, especially on such large ranges, is critical because metals and energetic materials are mobile in sandy environments and may migrate in groundwater, presenting a threat to human health and the environment. Groundwater flow had to be carefully assessed by determining its velocity and direction. The quality of the groundwater has also to be evaluated. Groundwater is used as a drinking water source for the base, to sustain aquatic ecosystems and also serves for irrigation. Consequently, any contamination could impact human health, irrigated crops, and aquatic ecosystems. In fact, groundwater flowing under CFB Shilo discharges as surface water in many springs southeast of the range, discharging into the Assiniboine River and into Marsh Creek to the north of the range. Both are highly sensitive areas for wildlife and humans receptors. Epinette Creek to the north is also used for irrigation. Biomass, such as prairie grass, has proven to bio-accumulate both metals and energetic materials. Therefore, prairie grass could represent a high potential intake source of these compounds for wildlife. Finally, since wildlife has access to the surface water and it can also be used for irrigation, water quality had to be assessed.

The 2000 initial study will be referred to in the present document as Phase I, which was completed by the publication of a DRDC-Val report [Ref. 22]. The second phase of the study was initiated following a tasking from Directorate Land Forces Services (DLFS) to assess the impacts of live firing in major army training ranges in the general goal of sustaining the activities. CFB Shilo was selected as the first base to initiate this important program, since a lot of efforts had already been devoted during Phase I. Moreover, at the same period, a joint venture between Canada and the United States was initiated to evaluate the fate of explosives in live firing ranges under the auspices of the Strategic Environmental Research and Development Program (SERDP), a major funding program in the U.S. Since the characterization of CFB Shilo had already begun with Phase I, Shilo was included as the first site for the collaborative work with the United States. Therefore, Canadian and U.S. scientists from both Cold Regions Research Engineering Laboratory (CRREL) and Environmental Laboratory (EL) with the support of both DLFS and SERDP accomplished Phase II.

This report describes the work carried out during Phase II at CFB Shilo between September-October 2001, and the results obtained from this sampling campaign. This study is the follow-up of the first phase conducted in September 2000 and addressed the two remaining battleruns, the rifle and grenade ranges. The anti-tank range was the only range not being sampled, since no level-one clearance had been conducted at that site, and it was judged unsafe for sampling. Since specific problems were identified during the first phase, localized sampling of biomass and soils around targets was conducted. More background samples were also collected to compare and assess the natural and anthropogenic contribution. This study was performed under the work breakdown element 12ny01, “Characterization of DND Sites Contaminated with Energetic Materials,” and was sponsored mainly by DLFS for the hydrogeological part, and SERDP for the surface soil sampling. All work was done in collaboration with the Institut national de la recherche scientifique (INRS) and Defence Construction Canada (DCC). DRDC-Val and INRS have both developed expertise in the characterization and the environmental fate of energetic materials in Canadian Forces training ranges and open detonation ranges.

Range description

CFB Shilo is located 25 km south-east of Brandon, Manitoba. The Base covers approximately 400 Km^2. Topographically, the Base lies on a relatively flat terrain with some dunes created after Glacial Lake Agassiz retreated from central Manitoba. Most of the area is treeless except for the forest in the northern parts. Tree groves are also scattered throughout the area. Boundaries of CFB Shilo consist mostly of rivers and parks. The southern part of the training area runs along the Assiniboine River. Spruce Woods Provincial Park defines the eastern limit of the training area. In addition, the Spruce Woods Provincial Park constitutes the northern border. Finally, the Cornwallis Rural Municipality serves as the western limit. A few cities and rural municipalities can be found around CFB Shilo. Shilo and Brandon are the most populated ones. CFB Shilo is divided into 5 regions from north to south (A, B, C, D, E). The administrative buildings are located in the north west of the area. Anti-tank, grenade and rifle ranges are located in the northern part of the base. Five battleruns used primarily by German troops were named Aachen, Berlin, Cologne, Deilinghofen and Essen. These battleruns are found respectively in region A to E. Each battlerun has its own area for petroleum refuelling named “Parkplatz”. Most of the targets found in the battleruns were pop-up targets instead of static targets, which represented a different problematic.

The drainage system includes two watersheds: the Epinette Creek and the Assiniboine River. The first one passes through the military base, while the second one is located along the southern border. Both rivers flow towards the east. CFB Shilo occupies part of the Assiniboine Delta Aquifer. This unconfined aquifer covers an area of 3 900 km2. The sand thickness is the smallest near the Assiniboine River ($\cong$ 6 m). Between Aachen and Essen battleruns, the thickness is maximum, approximately 30 m. The major uses of groundwater are for domestic purposes and for farmland irrigation around the base.

Experimental

Parameters and Analytical Methods

Soil and biomass samples were analysed for metals, energetic materials, and thorium-232. Groundwater and surface water samples were analysed for metals, anions, thorium-232 and energetic materials. Since no petroleum products including volatile organic compounds (VOCs) was found in Parkplatz during Phase I, no efforts were done for these parameters. Metals were analysed by Inductively Coupled Plasma Mass Spectrometry (ICP/MS) by an external laboratory (ETL) and all of the parameters available by this method were included in the study. For groundwater samples, energetic materials were analysed at DRDC-Val using the Gas Chromatography/Electron Capture Detector method that can produce a 0.004 ppb detection limit. Our quantification limit was 0.01 ppb. [Refs. 18-19]. Soil samples were dried in the dark, homogenized by adding acetone to form a slurry which was then evaporated. Soils were sieved through 25 mesh sieve and extracted at DRDC-Val and the extracts were shipped to CRREL for analysis. The quantification limits obtained for energetic materials in the present study varied between 0.5 and 12.5 ppb for soils depending of the analyte. No biomass samples were analysed for energetic materials, since no explosives were detected in Phase I. INRS conducted the following on site groundwater and surface water measurements: pH, electrical conductivity, temperature, salinity, dissolved oxygen and Eh. Furthermore, water level measurements, in situ permeability tests, and groundwater flow direction and velocity measurements were also conducted in monitoring wells. Thorium-232 was analysed by the Geological Survey of Canada using ICP/MS with a detection limit of 10 ppt for water samples and 0.1 ppm for soils.

Sample Handling and Treatment

Explosives are not volatile compounds and, therefore, no specific precautions, such as the use of sealed containers, had to be taken during sampling of media containing explosives. Soil samples were composites based on a minimum of 20-30 random subsamples and stored in polyethylene bags. The bags were immediately stored in ice coolers in the dark to avoid photodegradation of light-sensitive compounds. The soil samples were shipped frozen to the private lab (ETL) that split the samples into two subsamples after a thorough hand homogenization. One set of frozen samples was sent to DRDC-Val for explosives analysis and the other was digested and analyzed for metals. Water samples were collected and kept cold in 1-L amber glass, stabilized with sodium bisulfate (1.5 g) and sent to DRDC-Val for explosive analysis. Water samples for metals analyses were collected in standard 500-ml polyethylene bottles, and acidified to a pH of 2.

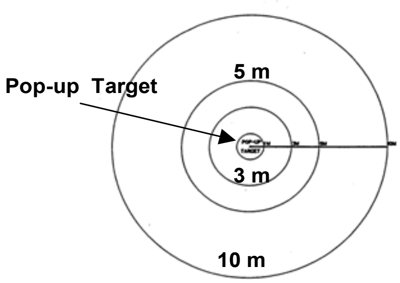
Soil and water samples for thorium analysis were shipped in 500-ml polyethylene jars to the Geological Survey of Canada. Water sample collected for nutrients and anions analysis were also collected in 500 ml polyethylene bottles and shipped cold to ETL. Biomass samples were collected in polyethylene bags, kept frozen in the dark, and sent to ETL. The samples were then cut in small pieces, homogenized, digested and analyzed for metals by ETL. Background soil and surface water samples were collected away from the ranges. Background wells were also installed up gradient and background groundwater samples were collected. Background biomass samples were also collected. Analyses were done twice for energetic materials (lab replicates), but were done only once for the other parameters. Field replicates (10%) were also sent for analysis. ETL reported their QA-QC including surrogates and blanks, detection limits, and quantification limits. Trip blanks and field blanks were also included in the QA/QC plan.

Soil Sampling Strategy

A total number of 156 soil samples was collected in Phase II. This included 21 backgrounds and 12 field duplicates (8%). All samples were analysed for metals (156), while a limited number were analysed for thorium (61) and energetic materials (108 soils- 8 field duplicates). Biomass samples (64) were collected including 3 field duplicates and 17 background samples. Groundwater (92) and surface water samples (22) were collected and analysed for metals and energetic materials. Background sampling locations were carefully chosen to represent the various geological formations that can be found in the area, 21 soil and 17 biomass background samples were collected in all directions around the training area. The background composite samples (30 subsamples) were collected in a random manner, in a circular pattern of approximately 20 meters in different locations inside and outside the base.

Each of the five battleruns in Shilo is approximately 2 km wide. Three battleruns were sampled during Phase I (Berlin, Deilinghofen and Essen), and the two remaining (Aachen and Cologne) during Phase II. A small part of Essen (Klein Essen) was also sampled. Deilinghofen and Essen battleruns were again visited during Phase II to re-sample a few targets to verify that the patterns obtained for soils in Phase I would be obtained in biomass. In Klein Essen, energetic materials were not screened since small arms bullets contain no explosive filling. The initial strategy planned for soil sampling was based on systematic sampling around a representative number of targets in battleruns and also hot spots (broken UXOs or debris, etc.). This strategy was used in previous studies on antitank ranges, which showed very distinct patterns of contamination around targets [Ref. 2]. However, the nature and type of firing exercises conducted in the battleruns were different from those conducted in antitank ranges. In this type of firing exercises, the ammunition makes the target flip, and pursues its flight until it reaches the end of the battlerun. The sampling strategy used during phase I was therefore adopted for the Aachen and Cologne ranges, using both linear transects and circular pattern at selected targets.

Briefly, the first sampling approach consisted of sampling targets (UXO, debris or pop-up targets) by compositing samples taken in a circular pattern. A minimum of 20 surface subsamples were collected at a depth of 0-2 cm within a radius of 1 meter, 1 to 3, 3 to 5 and 5 to 10 meters immediately surrounding the target areas, as shown in Figure 1. A rope marked at the prescribed distances was fixed to a stick as close as possible to the target. Circles were defined by turning the rope around the stick at the defined distance. The second sampling approach consisted in using a linear sampling pattern. This approach was used to evaluate whether the level of contamination by metal, thorium, or energetic materials was following a pattern with distance in the battleruns. If firing activities lead to the accumulation of contaminants in soils, higher levels would have been found at the end of battleruns, since most of the ammunitions fired were supposedly found there and the number of UXO items would be greater in these locations. Therefore, composite samples were collected at distances of 20, 40, 60, 100 and 120 % of the length of each battlerun. For all battleruns, an access road was located along the range and the transects were fixed with the help of the Global Positioning System (GPS). The linear samples corresponded to the point of the access road where the sampling team started walking perpendicularly to the range using a GPS to keep on a straight line. The sampling team walked for 1.5 km in a straight direction, and started sampling on their way back. The sample collected at the first 500-m distance was identified as Sample B, while the sample collected at the other 500-m distance was identified as Sample A, Sample A being the nearest to the access road (Figure 2). A minimum of 20 surface subsamples taken at 0-2 cm depth were collected to build each composite samples A and B corresponding to the two portions of 500m along transects in the middle of battleruns at each 20 % intervals from the parkplatzs [Ref. 22].



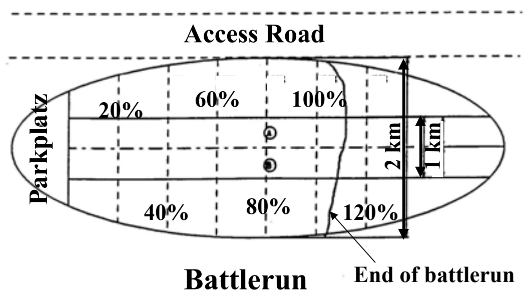


Figure 1. Circular pattern around targets **Figure2. Linear samples within battleruns**

During the drilling of the boreholes, subsurface soil samples were also collected prior to the drilling of the last 2 m. Sampling was conducted with a 51-mm splitspoon (60 cm long) at the depth of the middle of the screened interval of 1.52 m of the well. All of the soil samples were sent to INRS-ETE laboratory for grain size analysis and hydraulic conductivity estimation. The sediments encountered in the subsurface during drilling were visually described. Among the 41 boreholes, a total of four boreholes, namely SS-A-6, SS-B-6, SS-D-1 and SS-E-5, were sampled continuously every 60 cm with a 51-mm split-spoon sampler for soil classification and identification. The samples were composite samples at depth of 0 to 1, 1 to 2, 3 to 4, 5 to 6, 7 to 8, 9 to 10, 11 to 12, 13 to 14, 15 to 16 and 17 to 18 feet. Some duplicates were also collected. A total of 15 of these soil samples were sent to ETL for metal analysis. Detailed descriptions of the soil profiles were made and recorded in boreholes logs. Additional soil samples were also obtained along the screened interval directly from the auger to make the calibration-curve in the laboratory for the groundwater velocity measurements in the field with the Geoflo 40 flow meter.

Wherever biomass samples were collected, the method used consisted of building composite samples of indigenous living plants by cutting various types of plants randomly. A minimum of 20-30 subsamples of mixed biomass material was collected around targets. No biomass samples were collected along the transects in battleruns during Phase II since no trends were observed during Phase I. Only the upper part of the plants (without roots) was collected, since grazing animals rarely eat the roots. Moreover, explosives (particularly RDX and HMX) are known to bio-accumulate in the upper part of the plant. Metals could bio-accumulate either in the upper plant system or in the roots, depending of the solubility of the metals. Only one sample of roots was collected in the MILAN missile impact area to verify if the results obtained for thorium and other parameters would be higher in this sample. A total of 64 biomass samples including 17 background samples were collected in, and around the training areas. Metals were evaluated by digesting the biomass samples using a standard procedure in nitric acid. Biomass sampling in battleruns was concentrated around targets using the circular pattern approach.

For thorium-232, the composite soil samples were also formed of a minimum of 20 subsamples. The target areas for the MILAN missiles were identified and the approach using the circular pattern was applied to collect soil samples. These samples were analysed to compare with Phase I results and assess whether the concentrations were decreasing with time. Biomass samples were also collected around MILAN targets using the circular approach specific for targets. This was done to verify that bioaccumulation in plant tissues could be measured. A sample of plant roots was also collected in one occasion, since low solubility metals are known to bio-accumulate in plant roots instead of plant tissues. Some MILAN missile remains could still be found in Essen and were sampled.

Specific sampling strategies were used in grenade and rifle ranges. The grenade range was composed of a detonation area and a concrete bunker for the grenade thrower. Composite linear samples were collected in transects perpendicular to the grenade launching direction at distances of 5, 10, 15, 20, 30 and 35 m. Each transect measured 14 m long and was split into two portions of 7 m each, and named A and B samples. This sampling pattern was selected to verify whether a trend in the concentrations with the distance from the bunker could be observed. Moreover, a circular pattern would not have been helpful, since no targets were present on the range. Since there was only one crater in the detonation area, it was sampled as a potential hot spot (HS) by collecting 15 subsamples in the wall and at the bottom of the crater. In this range, no biomass samples were collected since the range was sandy and not vegetated.

The four rifle ranges in Shilo consisted in a series of numbered targets having sand butts (berms) in front of them. These butts are regularly sieved for metal debris. Surface soils, subsurface soils, and biomass samples were collected at three rifle ranges (1, 2 and 4). Rifle range Number 3 was not sampled based on its lower use by troops. Surface soils were collected from 0 to 10 cm deep and subsurface soils were collected using a hand-operated auger. All the soil collected in the auger after drilling in the subsurface was kept and represented a composite core sample of a depth between 5 and 50 cm. Eight composite surface soil samples were built and collected in front of groups of three nearby targets (24 targets sampled). Four subsurface soil samples were collected in each rifle range in front of four equally distance targets. Four biomass samples were collected since all the rifle ranges were highly vegetated around the sand butts and many deer droppings were seen on site. This means that many deer graze on this vegetation. Samples were collected in the area in front of six close targets.

Hydrogeological Survey

The field investigation included borehole drilling, monitoring well installation, development and testing for in situ hydraulic conductivity estimation, and in situ measurements of groundwater velocity and direction. A level 2 clearance proofing prior to drilling was done at all well locations to ensure the safety of drilling and technical personnel with the help of an electromagnetic device (EM-61) and a magnetometer. All soil, biomass, and water sampling locations were GPS surveyed. Most of the 36 boreholes were drilled with a Caterra rig, while a Nodwell-Brat 22 caterpillar was required for a few boreholes located in difficult access areas. Both rigs were equipped with a hollow-stem auger. For each site location, a probe hole was drilled with a 125-mm stem auger to determine the depth of the water table and then backfilled with bentonite. This initial step was executed to ensure that all observation wells would be drilled to at least 2 meters below the water table. Then, a 200-mm diameter borehole was drilled with the hollow-stem auger at least one meter away from the probe hole. This borehole was drilled to a depth of 2 m below the depth of the water table. To avoid cross-contamination between drilling sites, the drilling bit, augers and sampling equipment were cleaned [Ref. 22]. Monitoring wells were installed according to ASTM-D5092-90 standards. A one-way foot valve and a surge block were attached to the end of the tubing and the wells were developed. Each well was pumped for 3 to 5 hours until water was clear enough for sampling. Slug tests were made in all developed wells for an estimation of hydraulic conductivity of the sand formation. Locations (Northing and Easting) of monitoring wells and elevations of the top of the PVC tubing were made with the differential GPS technique using 2 GPS. Water level measurements were made after well development was completed and enough time had elapsed to allow the water table to recover its original level. An electronic measuring tape with a precision of ±0.5 cm was used to record the water depth in every well in relation to the top of the PVC tubing. The elevations of the water table measured in wells and of surface water from the topographic map were used to make the water table elevation map. In situ horizontal groundwater velocity and direction was measured with a Geoflo 40L flowmeter within the developed observation wells. Physicochemical parameters were measured in the field with YSI 63 and YSI 95 probes for water samples. These parameters included temperature, pH, conductivity, salinity, dissolved oxygen and redox potential. Groundwater was sampled for nutrients analysis, anions, metals, energetic material and thorium.

RESULTS AND DISCUSSION

Groundwater at CFB Shilo is characterized by a neutral pH (mean,7.56), a low alkalinity (170 to 240 mg/L), a low conductivity (340 to 450 μS (μohms/cm) for lab data and 225 to 535 μS for field data), a low total dissolved solids concentration (170 to 240 mg/L) and a very low concentration in anions (below detection limits)(bicarbonate, carbonate, chloride, sulphate). The redox potential averages 211 mV indicating an oxidizing environment. The high level of dissolved oxygen in groundwater (69%) confirms that aerobic environment exists. Groundwater velocity was estimated from the Geoflo 40L data and was consistent with the velocities calculated from other field data at 70 to 700 m/y with an average velocity of 350 m/y. Groundwater flow was generally from north to south.

Metal analysis in groundwater from 2001 sampling campaign generally showed concentrations much higher than those from samples collected in 2000. However, this is due to the fact that the 2001 samples were acidified in the field without filtration, thereby liberating metals adsorbed on particles. The two wells showing the highest metal concentrations are also those with the highest concentrations of dissolved solids (GW-C-8 TDS 1,700 mg/L, and MW-111, TDS 1,100 mg/L). This can be seen as the potential maximum charge of metal that can be brought to the GW level over the years both in solution and in suspension. These values do not, however, represent the concentrations of dissolved metals that would be present in groundwater at any time. Parameters exceeding guidelines were the following: aluminum (Al 83 wells), arsenic (As 7), antimony (Sb 34), barium (Ba 7), chromium (Cr 1), iron (Fe 93), lead (Pb 22, manganese (Mn 87), and selenium (Se 3). Aluminum, manganese and iron are naturally occurring in the environment; high concentrations are probably the results of desorption following acidification. The same phenomenon is probably responsible for the high concentrations of other metals. However, since these metals are sometimes linked to military activities, locations showing concentrations above guidelines were re-sampled in September 2002 to verify that these concentrations would not occur in filtered water samples. Generally, metals that exceeded criteria in groundwater also exceeded criteria in soils and biomass. However, metals exceeded the background level (BGL) or the Aquatic Guideline level (AQGL) more often in groundwater than in soils. This is not surprising since all contaminants, at a certain moment, reach the groundwater and this situation corresponds to a bigger surface source compared to surface sampling, which is localized source.

According to the state of the art in groundwater sampling, water samples should be filtered prior to acidification, but the fact that we did not do so, allowed us to evaluate the total contaminant present in both the dissolved and suspended state. This represents the worst-case scenario as a potential threat to groundwater quality. Since the pH of Shilo's groundwater is constant and neutral, the release of metals from the soils particles is very slow and does not present a threat for the time being. Our study demonstrated that metals are adsorbed onto particles that can be spread out by irrigation when unfiltered water is used. Along the southeastern boundary of the Shilo training area, farmers use the groundwater to irrigate crops. Therefore, the wells installed in the same area should be sampled on a yearly basis without filtration, as surveillance wells.

Thorium-232 concentrations in groundwater varied by three orders of magnitude. Concentrations ranged from <0.005 ppb (below detection limit) to 2.35 ppb. While even the highest result was one order of magnitude below the CCME guideline (24.5 ppb), several considerations should be kept in mind. Measured concentrations generally decreased with distance from MILAN firing ranges, several being below the detection limit. This is an indication of a measurable contribution of an anthropogenic source of Th in groundwater at CFB Shilo. When compared to the thorium BGL, 12 groundwater samples located in the target areas presented concentrations over this limit. The highest thorium concentration was found in Deilinghofen GW-D-8 near the firing area (2.35 ppb), and was one order of magnitude below the CCME standard of 24.5 ppb.The second and third highest concentrations were 0.907 ppb and 0.217 ppb, measured respectively in Cologne (GW-C-2) and Essen battleruns (GW-E-6). Analytical results for location GW-D-3, where the highest concentration was measured during Phase I in 2000 (1.15 ppb), revealed a lower concentration of 0.31 ppb in 2001. This may suggest that the contamination of thorium-232 is presently decreasing. No thorium was found either in the three springs or in the two supply wells of the base. The general pattern of thorium concentration in groundwater at CFB Shilo is one of decreasing concentrations with distance from targeted areas. For the soils, thorium is naturally occurring at 3 ppm at CFB Shilo and 99.99% of natural thorium is ^{232}Th. Some thorium hits were found close to targets at 6 ppm. This concentration suggests limited impacts and does not represent a major problem. In the biomass close to MILAN debris, plants bioaccumulated thorium at the ppb levels, with the root system accumulating more than the leaves and stem.

In Phase I (2000) energetic materials were not detected in the 39 groundwater samples at concentrations above 30 ppb. However, traces of TNT were seen in gas chromatograms below the quantification limit of the analytical instrument (30 ppb). One hundred one groundwater samples were analyzed in 2001 to confirm these results. Once again, no energetic materials were detected over the quantification limit of 0.01 ppb, meaning that earlier results for TNT were due to background noise of the analytical instrument.

During Phase II, metals were analyzed in 21 surface water samples. Very high concentrations of aluminum, iron and manganese exceeding both CCME drinking water and aquatic life criteria were measured in almost all samples. The measured concentrations were strongly related to the turbidity of the samples. These metals are naturally occurring in soils and sediments and cannot be linked directly to training activities. However, Aluminum is an important component of many munitions and could impact the environment. The same explanation is also valid for the numerous water samples exceeding aquatic life criteria for copper and arsenic as well as for the few samples exceeding aquatic life criteria for zinc, and drinking water criteria for arsenic, barium and antimony. One exception is zinc presence, which could be related to the use of smoke munitions that contain important amount of zinc. It would be unlikely that such type of munitions were fired over these lakes. The fact that no sample analyses showed excess in metals whose presence could be related to training activities (such as lead, mercury, etc.) is a strong indication that surface waters were not contaminated by military training activities. No energetic materials were found in surface water.

For biomass, Phase I demonstrated that no energetic materials (EM) were detected in any samples. For soils, some hits were found in battleruns and in the grenade range. In battleruns, the levels are generally low (below 1 ppm) with a tendency to accumulate around targets. Close to hot spots, explosives compounds and their derivatives were found probably due to leaching of EM out of the cracked shells, or due to deposition from low order detonations of EM-containing ordnance. EM from gun propellants were found in some localized spots that could be related to firing activities (missiles, rockets etc.), or to the burning of surplus propellants on site.

In general, metals and EM were related and were described by our characterization data range by range [Ref 23]. The grenade range presented contamination by both metals and EM. Traces of explosives were measured in samples from the entire area. Moreover, high levels of various metals were found everywhere as well. A new design for grenade ranges should be put in place if sustained activities are desired and will be recommended.

The situation encountered at riffle ranges demonstrated a clear impact of the firing activities with small arms. Both surface and subsurface soils showed the same trends with high levels of heavy metals detected. The samples were carefully sieved to avoid the inclusion of large metallic fragments in the digests. By doing this, we hoped to evaluate the potential contribution of metals attached to soil particles that can be breathed or simply capable of sedimentation or dissolution into the groundwater. However, very fine metallic particles that were included contributed to the total amount of metals and may not represent the bio-available metals. It is understood that large fragments are not bioavailable but will eventually contribute to groundwater contamination with time since, they will be slowly dissolved. Therefore, removing metallic fragments from the range soils periodically decreases the potential intake for groundwater contamination and represents a good practice that should be continued. Results obtained for soils in the rifle ranges correlated well with results obtained for the biomass samples. In particular, high levels of arsenic, copper, lead, strontium and zinc were found both in soils and biomass. Lead was found at the highest concentration compared to backgrounds and was as high as 789 times the BGL in plants. Antimony was also found at high levels in the biomass extracts; unfortunately, it was not included in the soil analysis series. A difference between soils and biomass concentrations was observed for alkaline metals (Na, Mg, K, and also Ca). These metals come from a de-icing procedure and are readily extracted by plants and the mixed contamination of plants by heavy metals and Ca-K-Mg creates a preferential intake of these contaminated plants by the wildlife. This was observed on the ranges where many deer tracks and droppings were seen. The salty taste of the Na-Mg-K attracts the deer to this heavy metal-contaminated vegetation. A fence around the rifle ranges should correct this situation.

As for the Shilo battleruns, the results obtained for the biomass samples demonstrated that higher levels of various metals were found in the vicinity of targets. The biomass results correlated well with the soil results where, in both cases, higher levels of various metals like cobalt, lead and strontium were found. Some higher results were obtained in plants for calcium, magnesium and sodium, while not observed in soils. This can be explained by the solubility of these particular alkaline and earth-alkaline metals. They are rapidly dissolved by rain or snow melt, can be taken up by plants or leach through to the groundwater leaving the concentrations in soils very low. The presence of these analytes at higher levels might attract wildlife because of the salty taste. Therefore, the wildlife present on the Shilo range might ingest preferentially these plants that contain not only the alkaline and earth-alkaline metals, but also the other metals phytoaccumulated as well in the biomass nearby targets. However, in general, the levels measured are quite low and no corrective actions have to be taken on battleruns related to either metals or EM.

Conclusion

In general, analytical results obtained for all parameters tested in all sample types showed no major environmental impacts related to the training activities. The study demonstrated that the sampling patterns that were designed for each type of ranges were adequate. They were efficient and led to useful data for each type of range. In particular, the combined approaches used in the battleruns (linear transects and circular patterns) were highly useful. The rifle range pattern was also well-adapted for the rifle berms and gave a complete coverage of the area. In the grenade range, we learned that the pattern used was fine, but the surface coverage was too small since contamination was found everywhere.

In general, the situation at CFB Shilo does not represent a high-risk situation that would justify recommending a halt to the training activities. Nevertheless, some points are still of concerns such as the high levels of metals in riffle ranges, the mixed contamination found in the grenade range, and the possibility of wildlife grazing on contaminated biomass. Finally, the work conducted at CFB Shilo training area will serve as a template and a reference study for all other Army training ranges. The following recommendations can be drawn from this study. A sureveillance program should be put in place for groundwater monitoring. Discussions should take place to design new riffle and grenade range intallations to take into account the environmental impact and sustain the activities. A fence should be built around the targets in riffle ranges. Some remains of MILAN missile were still found in the training area, mainly in the Essen battlerun. These missiles should be collected and treated as radioactive wastes and disposed of according to the radiological procedure put in place.

References

1. Ampleman, G., Thiboutot, S., Gagnon, A., Marois, A., Martel, R, and Lefebvre, R., “Study of the Impacts of OB/OD Activity on Soils and Groundwater at The Destruction Area in CFAD Dundurn”; DREV R-9827, Dec 1998, UNCLASSIFIED.
2. Thiboutot, S., Ampleman, G., Gagnon, A., Marois, A., Jenkins, T.F., Walsh, M.E., Thorne, P.G. and Ranney, T.A., “Characterisation of Antitank Firing Ranges at CFB Valcartier, WATC Wainwright and CFAD Dundurn”; DREV R-9809, Oct 1998, UNCLASSIFIED.

3. Thiboutot, S., Ampleman, G., Jenkins, T.F., Walsh, M.E., Thorne, P.G., Ranney, T.A. and Grant, G.L., “Assessment of Sampling Strategy for Explosives-Contaminated Soils”; Proceedings of the 90th Annual Air and Waste Management Society Meeting, Paper # 94-WP 101.08, Toronto, June 1997.
4. Jenkins, T.F., Walsh, M.E., Thorne, P.G., Thiboutot, S, Ampleman, G., Ranney, T.A. and Grant, C.L., “Assessment of Sampling Error Associated with Collection and Analysis of Soil Samples at a Firing Range Contaminated with HMX”; CRREL Special Report # 97-22, Sept 1997.
5. Jenkins, T.F., Walsh, M.E., Thorne, P.G., Miyares, P.H., Ranney, T.A., Grant, C.L. and Esparza, J.R., “Site characterization for explosives contamination at a military firing range impact area”; CRREL Special Report 98-9, 1998.
6. Brannon, J.M., Jenkins, T.F., Parker, L.V., Deliman, P., Gerald, J.A., Ruiz, C., Porter, B. and Davis, W.M., “Procedures for determining integrity of UXO and explosives soil contamination at firing ranges”; ERDC Technical Report; ERDC TR-00-4. (ERDC/CRREL MP-01-5604) 2000.
7. Pennington, J.C., Jenkins, T.F., Brannon, J.M., Lynch, J., Ranney, T.A., Berry, T.E. Jr., Hayes, C.A., Miyares, P.H., Walsh, M.E., Hewitt, A.D., Perron, N. and Delfino, J.J., “Distributional and fate of energetics on DoD test and training ranges: interim report 1”; Engineer Research and Development Center. Technical Report, ERDC TR-01-13, 2001.
8. Jenkins, T.F., Walsh, M.E., Thorne, P.G., Thiboutot, S., Ampleman, G., Ranney, T.A. and Grant, C.L., “Assessment of sampling error associated with collection and analysis of soil samples at a firing range contaminated with HMX”. CRREL Special Report 97-22, 1997.
9. Ampleman, G., Thiboutot, S., Désilets, S., Gagnon, A. and Marois, A., “Evaluation of the Soils Contamination by Explosives at CFB Chilliwack and CFAD Rocky Point”; DREV Report TR-2000-103, Nov 2000.
10. Thiboutot, S., Ampleman, G., Gagnon, A. and Marois, A., “Characterisation of an Unexploded Ordnance Contaminated Range (Tracadie Range) For Potential Contamination by Energetic Materials”; DREV Report TR-2000-102, Nov 2000.
11. Thiboutot, S., Ampleman, G., Dubé, P., Jenkins, T.F., Walsh, M.E., Hawari, J., Spencer, B. and Paquet, L., “Protocol for the Characterisation of Explosives Contaminated Sites”;DREV R-9721, 1998
12. Thiboutot, S., Ampleman, G. and Hewitt, A.D., “Guide for characterization of sites contaminated with energetic materials”. ERDC/CRREL TR-02-1, 2002.
13. Jenkins, T.F. and Walsh, M.E., “Development of an Analytical Method for Explosive Residues in Soil”; CRREL Report 87-7, U.S.A.T.H.M.A., Report # AMXTH-TE-FR-86102, June 1987.
14. Cragin, J.H., Legget, D.C., Foley, B.T. and Schumacher, P.W., “TNT, RDX and HMX Explosives in Soils and Sediments, Analysis Techniques and Drying Losses”; U.S.A.T.H.M.A. Report # AMX-TH-TE-FR-85038, Oct 1985.
15. Selim, H.M. and Iskandar, I.K., “Sorption-Desorption and Transport of TNT and RDX in Soils”; CRREL Report AD-A-285-570, May 1994.
16. Fellows, R., Harvey, S. and Cataldo, D., “An Evaluation of the Environmental Fate and Behaviour of Munitions Material (TNT) in Soil and Plant System”; Contract DE-AC06-76RLO 1830, Nov 1992.
17. Walsh, M.E. and Ranney, T.A., “Determination of nitroaromatic, nitramine, and nitrate ester explosives in water using SPE and GC-ECD: Comparison with HPLC”; CRREL Report 98-2, 1998.
18. Walsh, M. and Ranney, T., “Determination of nitroaromatic, nitramine, and nitrate ester explosives in water using solid-phase extraction and gas chromatography-electron capture detection: Comparison with high-performance liquid chromatography”; J. Chromatogr. Sc., 36(8): 406-416, 1998.
19. Walsh, M.E., “Determination of nitroaromatic, nitramine, and nitrate ester explosives in soil by gas chromatography and an electron capture detector”; Talanta, 54: 427-438, 2001.
20. Jenkins, T.F., Grant, C.L. Brar, G.S. Thorne, P.G. Schumacher P.W. and Ranney T.A., “Sampling error associated with collection and analysis of soil samples at TNT-contaminated sites”. Field Analytical Chemistry and Technology, 1(3): 151-163, 1997.
21. Walsh, M.E. and Ranney, T.A., “Determination of Nitroaromatic, Nitramine, and Nitrate Ester Explosives in Soils Using GC-ECD”; CRREL Report 99-12, 1999.
22. Thiboutot, S., Ampleman, G., Martel, R., Lefebvre, R. and Paradis, D., “Environmental Characterization of Canadian Forces Base Shilo Training area (Battleruns) Following Gates Closure”; DREV TR-2001-126, 2001.
23. Ampleman, G., Thiboutot, S., Lewis, J., Marois, A., Gagnon, A., Bouchard, M., Martel, R., Lefebvre, R., Gauthier, C., Ballard, J.M., Jenkins, T., Ranney, T. and Pennington, J., “Evaluation of the Impacts of Live Fire Training at CFB Shilo (Phase II)”; DRDC-Val TR 2003-XX, 230 pages, in press.

EVALUATION OF THE ENVIRONMENTAL IMPACT OF LIVE FIRING TRAINING AT CANADIAN FORCE BASE GAGETOWN

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Abstract

Troop readiness involves the live fire training with various types of ammunitions. An important portion of the Canadian ammunition stockpile is used in our own Country in training exercises. This operational activity is critical to insure that our troops are always in a readiness state to take action in any potential international conflicts or peace missions. It is imperative to sustain this activity by insuring that its environmental impact is kept at the lowest as possible. By better understanding the impacts of each type of live firing activity, the department of National Defence (DND) will be able to mitigate potential adverse impacts by changing the practices to minimize these adverse impacts. In this context, the first site to be characterized was the Canadian Force Base Shilo (CFB Shilo) where two major sampling campaigns were conducted in 2000 and 2001. From the study performed at CFB Shilo, it was observed that live firing training exercises and use of explosives might cause the dispersion of energetic compounds and metals in the environment. These compounds should be closely monitored due to their highly specific physical, chemical and toxicological properties. Moreover, there are strict regulations regarding metal concentrations in soils and groundwater. Contaminated groundwater plume going out of the training areas may end with the definitive closure of the base, an unacceptable outcome for DND. In Canada, important efforts have been spent over the last ten years to examine this particular environmental threat. The second training area selected in this programme was CFB Gagetown based on its intensive use by our militaries and allied forces and also based on its complementary geological and geographical context. This paper details the first phase of the study that consisted mainly in an hydrogeological determination of the groundwater flow, direction and contamination by explosives and metals of the northern part of CFB Gagetown and some preliminary soil sampling. The sampling and analytical methods are described and the results are presented. In 2001, 42 wells were drilled to characterize the underlying groundwater as well as the chemical characterization of the quality of the groundwater. Both metals and energetic materials were analyzed on all groundwater samples and on a few surface water samples. Some preliminary soil sampling was achieved including background samples. The next phase of the study will concentrate mainly on soil and biomass sampling and also on the surface water sampling. The southern part of the base will also be characterized for the hydrogeological context including the drilling of more wells and the collection of surface water samples. High clay type soils of CFB Gagetown represents a different problematic compared to the sandy soils encountered at CFB Shilo. This work should help the Canadian Forces to pursue their operational activities, while minimizing the impacts on the environment by providing a better comprehension of the source of contamination and helping to minimize the environmental impacts in the future.

Introduction

Testing and training ranges are key elements in maintaining the capability, readiness and interoperability of the Armed Forces. Moreover, many other countries use our training ranges under international agreements on a yearly basis. The current state of knowledge concerning the nature and extent of residual contamination of military testing and firing ranges is inadequate to ensure sound environmental management of these facilities as sustainable resources. Results of the on-going environmental research program will contribute to the development of recommendations for sustaining range activities while ensuring environmental stewardship and regulatory compliance. The potential for environmental impacts, including contamination of drinking water supplies, mandates that DND demonstrates responsible management of these facilities in order to continue testing and training activities. We should develop site characterization guidance and fill data gaps in fate and transport properties of high explosives residuals. Additional research will increase the knowledge base supporting the credibility of guidance and recommendations for range sustainability. The most extensive study achieved up to now was conducted at CFAD Dundum where the impact of the open detonation of Canadian obsolete munition was extensively studied (Ref.1). The first actual training range visited was the CFB Shilo training area where a detailed research was achieved to assess the environmental impacts of many types of live fire training (Ref. 2). Anti-tank firing ranges across Canada were also the topic of another study (Ref. 3). Moreover, many papers were written in the recent years concerning the fate and analysis of explosives in various types of sites (Ref. 4-13). This topic also is of very high interest and profile in the United States. There is a growing concern about the potential of military training activities leading to groundwater contamination on the Department of Defence (DOD) ranges. An example of this situation exists at the Massachusetts Military Reservation (MMR). Military training has been conducted for over forty years in the Training Range and Impact Area, which encompass almost 14,000 acres at MMR. The Training Range lies directly over the Cape Cod Aquifer, which has been designated as the sole drinking water source for Cape Cod. Energetic compounds and other military related compounds contaminated this aquifer, and consequently, the US EPA closed the MMR.

This paper presents the first characterization phase at CFB Gagetown training area. This phase was dedicated to the drilling of wells on the northern half of the base to collect groundwater samples and to perform the hydrogeological characterization of the site. Some surface water samples were also collected on specific locations over the entire base. The information gained is of strategic value for CFB Gagetown and represents a detailed study on the characterization of such a huge and intensively used training area. The Gagetown study will be complementary to the CFB Shilo one based on its different geological context and based also on the nature of the training conducted there. Another paper will be published in the proceedings of the Consoil 2003 symposium on the characterization of the Canadian Force Base Shilo and interested readers could refer to this other paper untitled “Evaluation of The Environmental Impact of Live Firing Training at Canadian Force Base Shilo”.

Range description

CFB Gagetown is located 20 km south-east of Fredericton, New-Brunswick. The Base covers an approximate area of 1100 square kilometres. The Training area can be divided in two physiographic regions, the New- Brunswick Lowlands in the north and the Ste-Croix Highlands in the south. The north half of the territory is use by the military as the Static Range Impact Areas (SRIAs), and the south half of the base as a General Manoeuvre Area. The Garnison is located in the north-west portion of the base. The first army training activities at CFB Gagetown took place in 1954. The base is still used today as one of the major training facilities of the Canadian Forces in Canada. Several military schools such as Infantry, Field Artillery, Air Defence, Armour Engineer and Armoured School are actively training in the Static Range Impact Areas (SRIAs). Such training activities represent potential contamination sources by energetic material and metals for underlying soil and groundwater.

Methodology

Field work was conducted for the sampling of surface soil, groundwater and surface water between October and December 2001 on the northern parts of all training ranges of CFB Gagetown and around base limits. The program included borehole drilling of 35 new monitoring wells installed in the northern half of the base to allow representative water sampling of the aquifer and on-site testing for physicochemical and hydrogeological characterisation. A total of over 59 water samples was collected and sent for analysis. Different physicochemical and hydrogeological tests were performed on most wells and surface water. All site locations were positioned with a GPS. Safety and proofing procedures were conducted with the use of an electromagnetic device (EM-61) and a magnetometer as detailed in a previous study (ref 2).

All groundwater and surface water samples were analysed for metals, major anions, and energetic materials (RDX, HMX, TNT, Tetryl and their main degradation by-products). Groundwater samples were analysed at DRDC-Val by Gas Chromatography/ Electron Capture Detector, a method that leads to low ppb detection limit for explosives. Analyses were performed with a GC HP6890 equipped with an ECD detector, an auto-injector HP7683 at an injection temperature of 250 ºC. This method was based on recent work published in the United States [12-13]. The quantification limits obtained for energetic materials in the present study was 0.1 ppb for aqueous samples based on interferences peaks. INRS conducted the following on site groundwater measurements: pH, electrical conductivity, temperature, dissolved oxygen and Eh. Furthermore, water level measurements; in situ permeability tests were also conducted. Metals were analysed by Inductively Coupled Plasma Mass Spectrometry (ICP/MS) by an RPC Laboratory.

The drilling and the installation of groundwater monitoring wells were conducted between October 9 and 22, 2001 following ASTM-D5092-90 standards. Well locations were selected according to the areas that were deemed best suited for the present investigation, in terms of their representative location, ease of access to the site in a safe manner and well positioning. All observation wells were to be drilled to at least 2 m below the water table. The sediments encountered during drilling were visually described for both types of drilling methods, augers and air rotary. Soil and rock cutting samples were collected from the air-rotary holes, generally at 1.5 m intervals or at changes in lithology. Well development involved the removing of fine sediment particles in soil around the screened interval and the rock formation by pumping water from each well. They were purged by a minimum of three times the equivalent volume of water in the borehole. The purge volume was sufficient to provide a representative and a good water quality sample. Steel casings were protected with locking covers that were installed at the top of each well. Four wells were presenting artesian (overflow) conditions (GAGE-4, AUSTERE-1, GREEN-5 and HERS-3). Surface water and groundwater sampling was conducted under the guidance of INRS. A total number of 51 groundwater and 8 surface water samples were collected. Groundwater samples were collected with the use of a Waterra Hydrolift II pump and a dedicated 13 mm HDPE tubing connected to a foot valve after the well development. Physicochemical parameters were measured in the field with probes (YSI, Solinst Instrument) including temperature (T), pH, conductivity (Cond), salinity (sal), dissolved oxygen (DO) and oxido-redox potential (ORP).

42 wells were sampled including two water supply wells for bivouac areas, (HERSEY and LAWFIELD), and five wells located around the Shirley Road dump (SRL series). Six wells were sampled in duplicate for quality control (GW-BURP-4T, GW-CASTLE-1, GW-HERS-4, GW-ROCK-4, GW-ROCK-1, GW-SBOUND-1). In addition, three samples of the water used for drilling were collected (DEC-EFF-1, LONG-1 and DAY-1). Water samples for energetic analysis were collected in 1 litre amber glass bottles, stabilized with sodium bisulphate (1.5 g) and stored cold for the transportation to DRDC-Val. For metal analysis, water samples were collected in standard 500 ml polyethylene bottles, field filtered and acidified to a pH of 2.

Slug tests were done in all developed wells (except for ARG-1, ARG-2 and ARG-3) for an assessment of the hydraulic conductivity of the rock formation. Data interpretation was done with the Bower&Rice method, Cooper method and Uffink method to evaluate the hydraulic conductivity. A pumping test and also packer tests were done at the location of PACK-1 and PACK-2. The pumping test had a total duration of 52 hours at a pumping rate of 5.6 l/min, which allowed the calculation of the hydraulic conductivity of the aquifer. Finally, several packer tests were done in the same two wells PACK-1 and PACK-2 to measure the transmissivity of the rock formation within a particular depth interval that can be isolated to find specific fracture horizons or to evaluate the transmissivity and permeability variation with depth. Water level measurements were made after well development. An electronic measuring tape (RST) with a precision of ± 0.5 cm was used to record the water depth in every well relative to the top of the PVC tubing. The water depth measurements were measured during October 2001 and measured again in December 2001. The elevation was calculated in relation to the survey of the well's PVC tubing or casing. The elevation of the water table measured in the wells and the elevation of surface water from the topographic map were used to produce the water table elevation map. The hydraulic head contours were calculated using the kriging interpolation method with the Surfer software.

UXO proofing was conducted prior drilling and consisted in surveying the ground to detect surface laid and buried metallic objects, thus ensuring the absence of (UXO). Clearance was conducted at all well locations by Dillon, to ensure the safety of drilling and technical personnel. The Dillon personnel along with Range Control and INRS personnel first used a GPS to locate and identify drilling sites. An electronic ordnance avoidance search was then performed at each of the 23 drilling sites located within the danger area boundaries. Afterward, a 10 m rectangle area was swept with a magnetometer and then repeated using an electromagnetometer, (EM-61). Cleared locations were identified with red ribbon and staked indicating the date and drilling site number.

To avoid cross-contamination between drilling sites, the drilling bit, augers and soil sampling equipment (split spoon) were thoroughly decontaminated between each locations. The CFB Gagetown employees provided GPS locations (northing and easting) of monitoring wells and elevations of the top of the PVC tubing. The error associated with GPS location is ± 2 m whereas the precision on elevation was ± 0.01 m with the technique using two GPS units.

Results and discussion

Geology

The studied area, which corresponds to the northern half of CFB Gagetown, covers approximately 275 km^2. The Gagetown base is part of the Appalachian physiographic region and geologic province. The northern half of the base is entirely underlain by clastic sedimentary rocks of the Pennsylvanian Cumberland Group while the southern half is underlain by diverse basement rocks of Silurian-Devonian age. The northern part, including the Static Range Impact Area, consists of a northward-dipping cover of red to grey sandstone, conglomerate and siltstone of Pennsylvanian age (280-320 My).The surficial geology of the Gagetown base is fairly uniform and consists predominantly of glacial sediments, mainly till, directly overlying bedrock. Till thickness were generally thin and discontinuous in the southern part of the base while moderately thick (1 to 6 m) and continuous in the northern part. The till matrix is typically very compact, reddish-brown and silt-rich over the gently rolling Pennsylvanian terrains in the northern part of the base while it is generally greyish, less compact and sandier in hilly Silurian-Devonian terrains in the southern part. These ubiquitous basal tills are characterised by low permeability while the loose, sandy ablation tills which cover some areas in the northern part of the base are much more permeable. Other types of surficial sediments (glaciofluvial, marine and alluvial) cover only small areas of the base, mainly valley floors, particularly that of the Nerepis River valley. The total thickness of Quaternary sediments observed during drilling varies from 1 to 23 m with a mean value of 5.8 m. The origin of the Quaternary sediments is essentially glacial. The grain size of these glacial sediments is characterized by the presence of a fine matrix, which gives a low permeability to the soil.

Hydrogeology

Twelve main water courses are draining CFB Gagetown. The highly developed surface water hydraulic network is very representative of the low permeability of underlying sediments.The aquifer underlying the area of the base is generally confined or semi-confined. The unconfined part was identified according to the superficial geology and drilling logs. Those areas include the southern part of the study area covering the Rockwell Wood North range and part of the Rockwell Impact. Unconfined conditions were also identified in Lawfield Impact, Greenfield Impact and in the north part of Wellington and Grenade ranges. Groundwater can be recharged directly by the infiltration of precipitation in those zones. The aquifer discharges ultimately into the Saint-John River. The piezometric map of the rock aquifer was generated based on water levels measured in wells drilled in October 2001 and also from current wells located on the base. The average depth of the water table below ground surface is 4.2 m with a maximum depth at 18.3 m. Groundwater flows in a radial pattern generally from south to north and from south to east and west. The observed hydraulic gradients vary from 0.001 to 0.024 with most values between 0.002 and 0.007 From this information, it is possible to evaluate the average velocity of the groundwater flow from a section (A-B) in the battle area. The linear groundwater velocity (v [L/T]) was evaluated from Equation [1]:

[1] $$v = K * i / n_{eff}$$

Where K is the mean hydraulic conductivity [L/T], i is the mean horizontal hydraulic gradient and n_{eff}, the effective porosity. Assuming a hydraulic gradient of 0.006, a porosity of 0.15 (ref. 21) and a hydraulic conductivity of 10^{-6} m/s, the average groundwater velocity is 3.5 mm/day or 1.3 m/year.

Hydraulic Properties of Sediments

The hydraulic properties of the sediments were determined by performing pumping, slug and Packers tests. The hydraulic tests realized in the rock formation showed highly variable hydraulic properties. Slug tests in the different rock formations showed that the mean hydraulic conductivity varied by three orders of magnitude, the gravel and sand formation being the more permeable and the mudstone and the brown sandstone the less permeable. However, the hydraulic conductivity may vary from 10^{-3} m/s to 10^{-10} m/s depending on the location of the test and the type of lithology tested. Pumping tests and packers tests were done in the conglomerate and the sandstone and the results varied over two orders of magnitude (10^{-5} to 10^{-7}). The geometric mean of hydraulic conductivity for this area was between 7.4×10^{-7} m/s to 1.4×10^{-6} m/s.

Groundwater

The first results of the geochemical analyses showed high values for alkalinity. The alkalinity measured in laboratory varies from 25 mg/L to 241 mg/L with a mean value of 88 mg/L. The pH was measured in laboratory and during the field campaign. Laboratory measurements showed generally alkaline pH with values higher than the recommended limits established by CCME. Values obtained in groundwater samples varied from 6.7 to 10 with a mean value of 8.34 (excluding SRL samples). Forty-two (42) groundwater samples were tested: 18 samples showed a pH higher than 8.5 (lab measurements) and 5 samples presented a pH lower than 6.5 (SRL samples: Dump). The remaining samples (19) showed pH values between 6.5 and 8.5. The pH measured in the field presented a mean value slightly lower (8.01), 14 of the 39 samples analysed in the field have shown pH values higher than 8.5.

Metals analyses revealed some concentrations higher than the water standard quality guidelines (WSQG) established by CCME (Table 1). The results of these detected metals are listed in Table 2. Overall, seven (7) metals were detected over the WSQG: aluminium, antimony, arsenic, iron, manganese, phosphor and vanadium. Metals that are more commonly detected are aluminium and manganese. The high values can be associated with sediments composition. Iron metal is also detected frequently; there is a good correlation between high values of iron and manganese. The high natural value for manganese implies generally higher concentration of iron. A clear relation between these two metals was established in the present study, which can indicate a natural source of these metals not necessarily associated with any contamination source. This would implies that both Fe and Mn are mostly from a non anthropogenic (i.e. natural) source.

Table 1: CCME WSQG for metals of interest

Element	Limit of Detection (RPC Laboratory) *ppb*	CCME Threshold Limit, *ppb*	Type of Criteria
Al	10	5-100	Aquatic Life
Al	10	5000	Irrigation or Livestock Watering
Antimony	0.1	-	Aquatic Life, Irrigation, Livestock Watering
Antimony	0.1	6	Drinking Water
As	1	5	Aquatic Life
As	1	100	Irrigation
As	1	25	Livestock Watering
As	1	25	Drinking Water
Fe	20	300	Aquatic life or Drinking water
Fe	20	5000	Irrigation
Mn	0.2	50	Drinking water
Mn	0.2	200	Irrigation
P	10	100	Drinking water
V	1	100	Irrigation, Livestock

Table 2: Samples with metal concentrations over the CCME WSQG

Sample	Metal >CCME threshold limits (ppb)	Sample	Metal >CCME threshold limits (ppb)
GW-ARG-1	Al (2170), As (36), Mn (50)	GW-Green-4	Mn (503)
GW-ARG-2	Al (1200), Mn (169)	GW-Haney-1	Al (108)
GW-ARG-3	Fe (5640), Mn (265)	GW-HANEY-3	Mn (179)
GW-ATR-1	Al (775), Fe (1340)	GW-HERS-4	Al (431), Fe (310)
GW-ATR-2	Mn (246)	GW-Law-2	Al (631), Fe (840), Mn (103), P (3350)
GW-AUSTER-1	Al (199), Mn (101)	GW-Law-4T	Mn (92)
GW-Burp-4R	Mn (122)	GW-Pack-1	Al (123)
GW-Burp-4T	Al (338), Fe (520), Mn (326)	GW-Rock-1	Al (154), As (535), P (430), Sb (17)
GW-Castle-1	Al (960), Fe (1780), Mn [illegible]	GW-Rock-4	Al (158), As (23)
GW-CDP-1	Al (338), Fe (530)	GW-SBound-1A	Al (151)
GW-DRUM-1	Mn (67)	Hersey North	Mn (77)
GW-GAGE-4	Al (100)	SRL 302X	Mn (335)
GW-GRE-1	Al (620), Fe (920), Mn (57)	SRL 303X	Al (881), Mn (456)
GW-GRE-2	Mn (219)	SRL 306X	Al (120), Fe (440), Mn (72)
GW-Green-5	Mn (61)	SRL 402X	Fe (1820), Mn (697)
GW-Green-3	Al (176), Fe (410), P(230)	SRL 403X	Fe (7020), Mn (3940)

When the results are compared to CCME WSQG, antimony was detected in only one well (ROCK-1). Arsenic was identified in ROCK-1 and ROCK-4 wells located in the same range and also in ARG-1 well. Finally, vanadium was found in the north zone of the military base in CASTLE-1. This well is located outside of the impact ranges area and downstream of the groundwater flow. Ten out of 42 wells analysed did not contain any metals with a concentration higher than the threshold limits.

Statistical Analysis

A statistical analysis was done with the geochemical results. The analysis showed that almost every element detected followed a log-normal distribution; the mean was calculated considering the logarithmic values. Only 6 elements do not present this kind of distribution: phosphorus, SiO_2, arsenic, lead, uranium and vanadium. This statistical analysis allowed the identification of a background concentration and to define a limit for a value, which can be considered abnormal. Samples located at the extremity of the log-normal curve were identified, the limits were chosen for a probability of 97.72% (2 times the standard deviation). In the general chemistry, the elements were aluminium, potassium, manganese, iron, zinc, chloride, sulphate and finally nitrates and nitrites. For metals, there was arsenic, barium, boron, antimony and lithium. From the 42 groundwater samples, 16 showed at least one value higher than the upper limit established by statistical analysis. Table 3 presents all the wells where those elements were detected. Values for potassium, nitrates and nitrites, sulphates and zinc are also higher in certain cases.

Table 3: Sample with element above statistical background

Sample	Detected Above Background	Sample	Detected Above Background
GW-ARG-1	Al (2.17 mg/L)	GW-Law-4T	Zn (0.187 mg/L)
GW-ARG-2	Ba (739 ppb)	GW-Pack-2	NO_2No_3 (1.19 mg/L),
GW-ARG-3	Fe (5.64 mg/L))	GW-Rock-1	SO_4(176mg/L), NO_2No_3 (0.81 mg/L), As (535ppb)
GW-Austere-1	Cl (166 mg/L), Sb (16.5 ppb)	SRL 302X	Mg (26.0 mg/L), B(312 ppb)
GW-GRE-2	K (4.18 mg/L), Li (26 ppb)	SRL 303X	B (204 ppb)
GW-HANEY-3	K (4.01 mg/L), Nitrates+Nitrites (1.18 mg/L),	SRL 306X	Mg (23.4 mg/L)
GW-Law-2	SO_4 (139 mg/L), Nitrates+Nitrites (1.36 mg/L)	SRL 402X	Zn (0.148 mg/L)
GW-Law-3	Zn (0.431 mg/L)	SRL 403X	Fe (7.02 mg/L), Mn (3.94 mg/L), Ba (1000 ppb)

The second statistical analysis had for objective to compare the concentrations with the regional geochemistry of south New-Brunswick. Two comparisons were done: (1) with the proximate background around the military base (270 samples) and (2) with a regional background, which covered south of New-Brunswick (896 samples). Based on preliminary analysis, 32 samples showed metal concentrations higher than the CCME WSQG (see Table 2). However, if the values of iron, manganese and aluminium were not taken into account, only 5 samples still showed high values for others metals. It was important to verify if the values for aluminium, iron and manganese were associated with abnormal concentration or with a high regional background. The statistical distribution of data for these elements was compared at two different scales with histograms on logarithmic data. This statistical method allowed the comparison of the mean value for each distribution. The abnormal concentration was established from a cumulative probability of 97.72%.

Results

Aluminium

The distribution of aluminium was quite similar for both regional and proximate backgrounds. Most values observed in the area were between 20 and 25 ppb). The distribution in Gagetown was different; the standard deviation was much higher. The mean value was also higher (65.3 ppb) compared to the proximate (42.1 ppb) and the regional (36.9 ppb) backgrounds. Eighteen of the 42 wells had their concentrations in aluminium higher than the 84.13% limit for proximate background (105 ppb). Ten wells were higher than the 97.72% limit (266 ppb). These wells included ARG-1, ARG-2, ATR-1, CASTLE-1, CDP-1, GRE-1, HERS-4, LAW-2, BURP-4T and SRL-303 X. Values for aluminium were higher in the area of the training range compared with the proximate and the regional background.

Iron

Values for iron did not seem abnormal when compared with the regional background. The mean values were 144.3 and 139.4 ppb for regional and proximate backgrounds respectively. The mean value in Gagetown Camp was lower at 92.64 ppb. The standard deviation for regional background was 505 ppb, therefore, it was commonly observed to get values between 0 and 632 ppb at a regional scale. In CFB Gagetown, only seven samples were higher than 632 ppb (ARG-3, ATR-1, CASTLE-1, GRE-1, LAW-2, SRL-402X, SRL 403X). From these samples, only two were higher than the regional 97.72% limit (ARG-3, SRL 403X).

Manganese

The distribution of manganese in Gagetown Training area was similar to both the regional and proximate backgrounds. The mean value observed was slightly higher. Only one sample seemed to be abnormal and it was located in the dump (SRL-403X). The mean values varied from 38.9 ppb to 42.3 ppb, from the regional scale to the Gagetown camp. Those values were very close to the CCME limits for drinking water (50 ppb).

Energetics

Energetic material were analysed for in 42 groundwater samples, two water samples used for drilling, one sample from cleaning water and one sample from the field blank. The analytical method used normally allows a detection limit lower than 0.1 ppb. In this case, based on the background noise and the results obtained for blanks, the quantification limit was established at 0.1 ppb. 17 samples presented quantifiable amounts of either TNT, RDX, HMX or Tetryl (see Table 4).

Table 4:Samples with energetic compounds detected

Sample	Energetic detected (ppb)	Sample	Energetic detected (ppb)
GW-ATR-1	RDX (1.6)	GW-LAW-4R	RDX (1.6)
GW-ATR-2	RDX (1.6)	GW-LAW-4T	RDX (1.6)
GW-BURP-4R	RDX (1.6)	GW-SBOUND-1	TNT (1.0)
GW-BURP-4T	TNT (1.1)	HERSEY NORTH	RDX (1.6)
GW-BURP-4T-A	RDX (1.6)	SRL 302X	RDX (1.6)
GW-DRUM-1	RDX (1.6)	SRL 306X	HMX (2.1)
GW-HANEY-3	RDX (1.7)	SW-23	Tetryl (2.2)
GW-HANEY-3	RDX (1.6)	SW-SWAN	Tetryl (2.2)
GW-HERS-3	RDX (1.6)		

Out of these 17 samples, the 2 antitank range samples presented levels of RDX around 1.5 ppb. At BURP location, three out of the four samples presented either RDX or TNT. One DRUM sample presented RDX at 1.6 ppb. At Haney and Hershey ranges, two samples presented RDX. Two dump samples (SLR 302X and 306X) presented HMX or RDX. The south boundary of the demolition range presented TNT and two samples from the LAW rocket range presented RDX. These results indicated an impact of the training activity on specific ranges. The levels of explosive found were very low but they were still quantifiable which is somewhat surprising considering the depth of the groundwater and the low-permeability of the Gagetown soil. Fractured rock or clay could explain the slow migration of explosives at the site. In two surface water samples, we found 2.2 ppb of Tetryl. This is highly surprising and these results will have to be confirmed at the next sampling campaign.

Surface Water

During the sampling campaign, 8 surface water samples were collected around the military base in the main streams. Surface water samples collected presented pH values lower than the groundwater samples mean value of 7.4 vs. 8.34 for groundwater) and the alkalinity is also lower (mean value of 13.6 mg/L for surface water versus 88 mg/L for groundwater). All pH were within the recommended values established by CCME (6.5 and 8.5) except for one sample, which had a pH (measured in field) of 8.52 (SW-HARTS). Field measurements were generally higher than laboratory measurements (mean of 8.0 vs. 7.45). Metal analyses did not show any concentration higher than CCME threshold limits. However, iron values were higher than the recommended 0.3 mg/L in 7 of 8 samples.

Quality Control of Water Samples

Quality control of water samples included 6 blanks from laboratory, 1 field blank and six duplicate samples. The water used for drilling was also sampled to verify the possibility of a cross-contamination. Laboratory blanks did not show any trace of metals and all the duplicates show similar results. Laboratory results seemed to be reliable in regard with these observations. However, the field blank (CORM-1) sent to the laboratory had some peeks in the following metals: manganese (4 ppb), copper (20 ppb), zinc (9 ppb), lead (0.3 ppb) and aluminium (5 ppb). Values detected were very close to the detection limits but these results can indicate a contamination during sampling or an error during laboratory analysis.

Conclusions

Hydrogeological Context

The surficial geology of the Gagetown base was fairly uniform and consisted predominantly of glacial sediments, mainly till, directly overlying bedrock. Till thickness varied significantly within the studied area, were generally thin and discontinuous in the southern part of the base while moderately thick (1 to 6 m) and continuous in the northern part. These ubiquitous basal tills were characterised by low permeability while the loose, sandy ablation tills which cover some areas in the northern part of the base were much more permeable. The total thickness of Quaternary sediments observed during drilling varied from 1 to 23 m with a mean value of 5.8 m.

The hydraulic properties of bedrock and sediments were determined by a pumping test, packer tests on two wells and slug tests on most observation wells. These properties were quite variable and were related to the diverse lithologies underlying the base. The average hydraulic conductivity was relatively low (10^{-6} to 10^{-7} m/s) but it can be locally high such as in sand and gravel accumulations (10^{-3} m/s) as well as in some conglomerate and sandstone horizons.

The average depth of the water level under the land surface was 4.2 m with a maximum depth of 18.3 m. Groundwater flow was radial and generally from south to north. The aquifer discharges ultimately into the Saint-John River. The flow pattern is influenced by the topography of the land surface and represents a good example of a gravity-driven groundwater flow system. The observed hydraulic gradients vary from 0.001 to 0.024 with most values lying between 0.002 and 0.007. Such gradients imply a slow ground water flow velocity in the order of 1 to 2 m/yr. The aquifer underlying the base is generally confined or semi-confined. The unconfined part was identified according to the surficial geology and drilling logs. Those areas include the southern part of the study area covering the Rockwell Wood North range and part of the Rockwell Impact. Unconfined conditions were also identified in Lawfield Impact, Greenfield Impact and in the north part of Wellington and Grenade ranges. Groundwater can be recharged directly by the infiltration of precipitation in those zones. In such unconfined areas the aquifer is thus more vulnerable to contamination from surface activity. The potential for contamination is also higher in areas were surface sediments are thin or very permeable and the water level is near the land surface.

Groundwater Environmental Conditions

Groundwater and surface water sampling was done at various locations within and outside the base limit to determine the natural background quality of groundwater and the potential impact of training activities on groundwater. Most groundwater samples had a high pH (alkaline conditions). The two most common water types encountered were Na-HCO3 and Ca-HCO3 waters. The first of these water types was associated with higher pH values, higher aluminium concentrations and a slightly higher alkalinity. The Ca-HCO3 water type was found mostly under unconfined conditions whereas the Na-HCO3 water type was associated to confined or semi-confined conditions. Analyses for dissolved metals in groundwater samples revealed that the concentrations of seven (7) elements in 32 wells exceeded CCME recommendations. These elements are aluminium (Al), iron (Fe), manganese (Mn), arsenic (As), phosphorous (P), vanadium (V) and antimony (Sb). The first three elements (Al, Fe, Mn) had high concentrations in almost every well. The regional background concentrations of the high concentration elements were determined based on available concentrations in the New Brunswick groundwater quality database. The regional background values showed that the high iron and manganese concentrations found within CFB Gagetown were related to natural high concentrations in this area rather than to training activities. However, aluminium concentrations in groundwater found within the base were higher than the regional background. High V, P and Sb concentrations were found in a single well and could be related to a local contamination. The high arsenic levels found in two wells within the Rockwell impact could be related either to a local arsenopyrite presence in the aquifer rock or to a local unidentified anthropic source. The generally high values of the pH found in the Gagetown groundwater might lead to higher levels of various metals as seen in the different analysis results. This will have to be kept in mind when the concentrations of the correspondent metals in soils of the training area are known.

Energetic materials were also analysed in the water samples. Of these samples, 17 present quantifiable amounts of TNT, RDX, HMX or Tetryl. All samples presenting these levels were collected in live firing ranges. The levels found are all below 2.5 ppb. However, considering the 2 ppb limit in drinking water for explosives, it is imperative to verify if there are plumes of dissolved explosive migrating outside of the range and outside of the boundaries of the training area. These results will be confirmed in the next sampling campaign scheduled for the fall of 2002.

Based on the results of our groundwater sampling in the northern half of CFB Gagetown in 2001, there does not seem to be a high level or widespread regional contamination of groundwater related to training activities. However, it is still surprising to detect evidences of low levels of contamination, especially by energetic materials, given the context found at the base. The relatively low permeability surficial material and deep groundwater levels would not lead to easy contamination of this aquifer. These favourable conditions are perhaps offset by the fractured nature, low porosity, and probably low organic content of the aquifer, which would favour dissolved contaminant transport. Given these results it will be important to carry the second phase of the characterisation efforts in 2002, especially to determine the contamination levels found in soils and vegetation. These data will better indicate if the intense training activities in CFB Gagetown lead to the accumulation of contamination on the soil surface that might eventually reach groundwater or if on the contrary the low levels now found in groundwater properly reflect low contaminant inputs from the surface.

Recommendations

The main recommendation is to complete the second phase of the characterisation program involved in this research project. Activities in this second phase will be based on the results obtained thus far and tailored to complete our understanding of CFB Gagetown. Among these activities, the further analysis of repeat samples from existing wells for energetic materials will be important to confirm the levels detected in the 2001 sampling campaign. Certain wells where slug test results were inconclusive will be tested again in 2002. The second phase will focus on the southern part of the base and it will take advantage of the presence of existing wells for the sampling. New monitoring wells will also be installed in the periphery of the base to better assess background levels outside the base and determine if contaminants are detected beyond the base boundary, especially in areas where groundwater is a source of drinking water. Complementary to groundwater sampling, more surface water samples need to be taken because of the relatively low permeability of the surficial sediments, which leads to important surface water runoff and an important surface water network. Contaminants are thus susceptible to be found in surface water if emissions take place in relation with training activities. The important activity in the second phase will be sampling of soils and vegetation and their analysis for metals and energetic materials at selected locations in the range and training area. In addition, recent discussions with US scientists revealed that fixed gun firing positions often present contamination by both nitroglyceryne and 2-4 dinitrotoluene. Therefore, training area fixed firing position will be tested for those 2 analytes. Moreover, two new analytes will also be included in the phase II study. These are perchlorates and hexachloroethane by-products (HC). These analytes will be included based on new information gained since the realization of the phase I study. Perchlorates are present in many types of propellants. Unburned propellant can therefore be a source of perchlorate contamination. Also, many smoke generators used in Gagetown contains both perchlorate and hexachloroethane. Last year three tons of HC based ammunitions were fired in the training area. HC is a chlorinated hydrocarbon persistent in the environment and will be included in phase II.

Reference

1. Ampleman, G., Thiboutot, S., Gagnon, A., Marois, A., Martel, R, and Lefebvre, R., “Study of the Impacts of OB/OD Activity on Soils and Groundwater at The Destruction Area in CFAD Dundurn”; DREV R-9827, December 1998.
2. Thiboutot, S., Ampleman, G., Martel, R., Paradis, D., and Lefebvre, R., “Environmental Characterisation of Canadian Forces Base Shilo Training Area (battleruns) following GATES Closure”; DREV TR 2001-126, November 2001
3. Thiboutot, S., Ampleman, G., Gagnon, A., Marois, A., Jenkins, T.F., Walsh, M.E., Thorne, P.G. and Ranney, T.A., “Characterisation of Antitank Firing Ranges at CFB Valcartier, WATC Wainwright and CFAD Dundurn”; DREV R-9809, October 1998.
4. Approaches for the Remediation of Federal Facility Sites Contaminated with Explosives or Radioactive Wastes"; EPA Handbook # EPA/625/R-93/013, September 1993.
5. Checkai, R.T., Major, M.A., Nwanguma, R.O., Phillips, C.T. and Sadusky, M.C., "Transport and Fate of Nitroaromatic and Nitramine Explosives in Soils From Open Burning/Open Detonation Operations"; Edgewood Research Development & Engineering Center, report ERDEC-TR-136, December 1993.
6. Jenkins, T.F., Walsh, M.E., "Development of an Analytical Method for Explosive Residues in Soil"; CRREL Report 87-7, U.S.A.T.H.M.A., Report # AMXTH-TE-FR-86102, June 1987.
7. Thiboutot, S., Ampleman, G., Jenkins, T.F., Walsh, M.E., Thorne, P.G., Ranney, T.A. and Grant, G.L., “Assessment of Sampling Strategy for Explosives-Contaminated Soils”; Proceedings of the 90th Annual Air and Waste Management Society Meeting, Paper # 94-WP 101.08, Toronto, June 1997.
8. Jenkins, T.F., Walsh, M.E., Thorne, P.G., Thiboutot, S, Ampleman, G., Ranney, T.A. and Grant, C.L., “Assessment of Sampling Error Associated with Collection and Analysis of Soil Samples at a Firing Range Contaminated with HMX”; CRREL Special Report # 97-22, September 1997.
9. Thiboutot, S., Ampleman, G., Dubé, P., Jenkins, T.F., Walsh, M.E., Hawari, J., Spencer, B. and Paquet, L., “Protocol for the Characterisation of Explosives Contaminated Sites”; DREV R-9721, April 1998.
10. Ampleman, G., Thiboutot, S., Désilets, S., Gagnon, A. and Marois, A., “Evaluation of the Soils Contamination by Explosives at CFB Chilliwack and CFAD Rocky Point”; DREV Report TR-2000-103, Nov 2000.
11. Thiboutot, S., Ampleman, G., Gagnon, A. and Marois, A., “Characterisation of an Unexploded Ordnance Contaminated Range (Tracadie Range) For Potential Contamination by Energetic Materials”; DREV Report TR-2000-102, Nov 2000.
12. Walsh, M.E., Ranney, T.A., “Determination of Nitroaromatic, Nitramine, and Nitrate Ester Explosives in Water using Solid Phase Extraction and GC-ECD”; CRREL Report 98-2,1998.
13. Walsh, M.E., Ranney, T.A., “Determination of Nitroaromatic, Nitramine, and Nitrate Ester Explosives in Soils Using GC-ECD”; CRREL Report 99-12, 1999.

IMAGE-TRAIN: INNOVATIVE MANAGEMENT OF GROUNDWATER RESOURCES IN EUROPE – TRAINING AND RTD CO-ORDINATION PROJECT

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Abstract

The EU-funded project IMAGE-TRAIN (Innovative Management of Groundwater Resources in Europe – Training and RTD Co-ordination Project) has the ambition to improve cooperation and interaction between ongoing research projects in the field of soil and groundwater contamination and to communicate new technology achievements to young scientists by means of training courses. IMAGE-TRAIN is a three year project which started in September 2001 and operates at two levels. (1) At the level of senior scientists cluster meetings for researchers of ongoing research projects are being organised with the objective to establish topic links between RTD projects dealing with contaminated land and groundwater and to promote their practical application. Furthermore, practical case studies with selected experts are being organised to perform short studies on emerging groundwater and soil issues. (2) At the level of junior scientists Advanced Study Courses are being organised with the objective to quickly transfer existing and emerging knowledge to young European academics. Last not least, IMAGE-TRAIN is maintaining a communication platform for young scientists dealing with groundwater and soil science which can be found on the project's website.

Project-Structure

IMAGE-TRAIN is an Accompanying Measure funded by the Fifth Framework Programme (FP5) on research, technological development and demonstration. Main driving forces of this project are

- improvement of knowledge transfer (training of young scientists, better communication between established scientists),
- better integration of EU Accession countries in the research community,
- establishment of concerted research efforts by combining research projects and establishing research clusters, and
- practical implementation of current research activities along practical case studies.

IMAGE-TRAIN has the ambition to improve cooperation and interaction between ongoing research projects in the field of soil and groundwater contamination and communicate new technology achievements to young scientists by means of conferences and training courses. IMAGE-TRAIN is a three year project which started in September 2001 and operates at two levels.

- Senior level: At this level Cluster Meetings for researchers of ongoing research projects are being organised with the objective to establish topic links between RTD projects, dealing with contaminated land and groundwater and to promote their practical application and by organising practical case studies with selected experts to perform short feasibility studies related to current groundwater or mine water problems.
- Junior level: At this level Advanced Study Courses are being organised with the objective to quickly transfer existing and emerging knowledge to young European academics.

The RTD projects INCORE, PEREBAR and PIRAMID[1] form the basis to establish such topic-links. In the course of IMAGE-TRAIN other relevant RTD projects are being identified and considered to extend the clustering process. Major focus of IMAGE-TRAIN is to establish an efficient knowledge and information transfer towards the scientific community and potential end-users, with specific emphasis on the situation in EU Accession Countries. This is currently achieved by (see also Table 1 and 2)

- three *Advanced Study Courses* for academics and young scientists,
- *clustering* of ongoing RTD projects along 3 Cluster Meetings, and
- application of findings along practical *case studies.*

Table 1: Overview and description of key IMAGE-TRAIN activities and their impact

	Activity	**Description**	**Target Group**	**Impact**
Senior Level	3 Cluster Meetings	Scientific conferences	Researchers of ongoing research projects	Information exchange and better coherence between thematically related projects Input to Advanced Study Courses
	3 Case Studies	Joint expert opinions on defined topics	Selected experts	Reports and reviews on emerging topics
Junior Level	3 Advanced Study Courses	Up-to date training on innovative groundwater remediation technologies	Scientists, engineers, and consultants	Quicker understanding and application of new innovative groundwater remediation technologies

All IMAGE-TRAIN products (newsletter, proceedings, summary reports and other) can be directly downloaded from the project's website: http://www.image-trian.net/.

Current Status of the project (July 2002)

Past Events:

The **1st IMAGE-TRAIN Cluster Meeting** was held in Karlsruhe in November 2001 and served on the one hand as Kick-off meeting for the Accompanying Measure IMAGE-TRAIN, and on the other hand as Mid-Term Review for the IMAGE-TRAIN core projects. Representatives from 30 European organisations all being involved in the EU research projects INCORE, PEREBAR, and PIRAMID reported about their scientific achievements at project mid-term. The proceedings include statements of the project co-ordinators at project mid-term, a synthesis of the meeting, and 30 papers, covering key aspects of groundwater and mine water management (IMAGE-TRAIN, 2002).

The **1st IMAGE-TRAIN Advanced Study Course** with the title "*Innovative Groundwater Management Technologies"* was held in June 2003 in Katowice (Poland). 37 young researchers from 20 European countries participated at the course. 11 lecturers mainly from the core projects presented detailed results from their current research work. The programme focused on passive in-situ remediation technologies for contaminated groundwater and acid mine drainages, ground water and human health risk assessment and integral groundwater investigation and included an excursion to the Tarnowskie Góry site, a former chemical plant which is considered as national hot spot site in Poland. The course

1 Acronyms for ongoing FP5 research projects:
INCORE, Integrated concept for groundwater remediation, http://www.umweltwirtschaft-uw.de/incore/;
PEREBAR, Long-term Performance of Permeable Reactive Barriers used for the Remediation of Contaminated Groundwater, http://www.perebar.bam.de/
PIRAMID, Passive In-situ Remediation of Acidic Mine / Industrial Drainage, http://www.piramid.org/

was evaluated by the participants by means of a questionnaire and received excellent results. Contents of the course were published in a review report (IMAGE-TRAIN, 2003a).

The 1st **IMAGE-TRAIN Case Study** was carried out under the lead of Newcastle University. Four experts on saline mine waters in Poland, Spain, and Germany provided their input and expertise concerning saline mine water management. The results of this study are summarised in a review paper *"Review of Saline Mine Water Management and Methods for Managing them"* which is available form the project's website (Gandy and Younger, 2002).

The **2nd IMAGE-TRAIN Cluster Meeting** "*Sustainable Management of Contaminated Land and Groundwater in Urban Areas"* was held in Cracow from October 2 – 4, 2002. The purpose of this meeting was to focus on groundwater pressures in urban areas due to intensive landuse. Furthermore, this event included a specific workshop focussing on the new project tools of the European Commission's Sixth Framework Programme (FP6) on research, technological development and demonstration. The proceedings of this meeting include 20 summary papers of FP5 research projects dealing with soil and groundwater contamination and a summary of the 1st IMAGE-TRAIN Case Study (IMAGE-TRAIN, 2003a).

Future Events:

The **2nd IMAGE-TRAIN Case Study** is currently carried out under the lead of Tuebingen University. Key objective is to review deliverables of FP5 research projects dealing with groundwater contamination in view of their practicability for the future groundwater directive. Interim results of this study are presented along CONSOIL 2003 (Bittens and Prokop, 2003) and final results will be published in a specific review report and will also be available through the project's website.

The **2nd IMAGE-TRAIN Advanced Study Course** is dedicated to *"Management of Groundwater in Mining Areas"* and will be held in Pécs-Hungary in June 2003. The venue is close to an abandoned uranium ore mine and processing site which will be destination of a one day excursion. The course will focus on cost-effective remediation of mining effluents and management of groundwater in areas affected by contamination from mining activities. Again, the contents of the course will be published in a review report and broadly disseminated.

Table 2: Timetable of key IMAGE-TRAIN activities (CM=Cluster Meeting, ASC= Advanced Study Course, CS=Case Study)

Date	**Type**	**Venue**	***Title*** **; Target Audience**
Nov. 01	CM	Karlsruhe (DE)	*IMAGE-TRAIN Kick-off Meeting;* Target audience: researchers of projects PEREBAR, INCORE, PIRAMID
June 02	ASC	Katwoice (PL)	*Innovative Groundwater Management Technologies;* Target audience: selected junior scientists and engineers from EU and EU Accession countries
Oct. 02	CS	Cracow (PL)	Review of Saline Mine Water Management and Methods for Managing them; Target audience: researches dealing with mine water problems
Oct. 02	CM	Cracow (PL)	Sustainable Management of Contaminated Land and Groundwater in Urban Areas + FP6 Workshop; Target audience: researchers from FP5 research projects
June 03	ASC	Pécs (HU)	*Groundwater Management in Mining Areas;* Target audience: selected junior scientists and engineers from EU and EU Accession countries
Oct. 03	CM	Vienna (AT)	*Are EU FP5 Research Results from the Key Action Water – Pollution Prevention Fit for Use?*; Target audience: European researchers and stakeholder groups
Oct. 03	CS	Vienna (AT)	*Application and Practice Report of EU FP5 Research Results in the Area Key Action Water – Pollution Prevention*; Target audience: researches dealing with groundwater contamination
May 04	ASC	(RO)	*Title to be determined;* Target audience: selected junior scientists and engineers from EU and EU Accession countries
June 04	CS	To be defined	*To be defined*; Target audience: researches dealing with groundwater contamination

Public access to the derived results and information is provided through the project's website (http://www.image-train.net/). Announcements, proceedings from Cluster Meetings, review reports from Advanced Study Courses can be directly downloaded. Finally it should be mentioned that IMAGE-TRAIN is maintaining a Communication Platform for Young Scientists dealing with groundwater and soil science which can be found on the project's website. Main objective of this venture is to create a platform which allows Ph.D. students and other young scientists to present their research work and to get readily into contact with others who have similar interests or work at related fields.

References

IMAGE-TRAIN (2003a in print), *"Innovative Groundwater Management Technologies"*, Review report of the 1st IMAGE-TRAIN Advanced Study Course in Katowice-Poland from June 24 – 28, Prokop G. (editor), published in *„Tübinger geowissenschaftliche Arbeiten – Reihe C: Hydro-, Ingenieur- und Umweltgeologie"*, Zentrum für Angewandte Geowissenschaften – Eberhard Karls Universität Tübingen, Germany.

IMAGE-TRAIN (2002), *"Innovative Management of Groundwater Resources in Europe"*, Proceedings of the 1st IMAGE-TRAIN Cluster Meeting in Karlsruhe from November 7 – 9 2001, Prokop, G. (editor), ISBN 3-85457-631-5, published by the Federal Environment Agency – Austria. An on-line version can be downloaded from http://www.image-train.net.

Gandy C.J., Younger P. (2002), *"Review of Saline Mine Water Management and Methods for Managing them"* Review paper of the 1st IMAGE-TRAIN case study available at the project's website: http://www.image-train.net.

IMAGE-TRAIN (2003b), "*Sustainable Management of Contaminated Land and Groundwater in Urban Areas"*, Proceedings of the 2nd IMAGE-TRAIN Cluster Meeting in Cracow from October 2 – 4 2002, Prokop, G. (editor), published by the Federal Environment Agency – Austria. An on-line version can be downloaded from http://www.image-train.net.

Bittens M., Prokop G. (2003) *"Application and Practice Report of EU FP5 Research Results in the Area Key Action Water – Pollution Prevention: Are Results Fit for Use?"* Proceedings of the 8th International FZK/TNO Conference on Contaminated Soil from May 12 to May 16 2003 in Gent, Belgium.

IMPLEMENTATION OF THE NATIONAL ECOLOGICAL NETWORK REQUIRES SPACE.

FROM BOTTLENECKS TO OPPORTUNITIES

An initiative of Tauw bv [1]:
in consortium with
Foundation Duinbehoud, Province of Zuid-Holland en Municipality of Noordwijkerhout

A large number of former landfill sites are present in The Netherlands. A considerable number of these landfills are located in rural areas. These landfills are generally fallow or hold a low quality function cause of their potential environmental risks. Quite often landfills in rural areas are situated within the National Ecological Network (EHS). The Dutch government has the intention to create the EHS by the end of 2018. Due to the limited availability of land and the high land prices, realising the EHS is a complex and slow process.

At present it is unclear if landfills can have a high environmental use within the EHS after an ecological and environmental redevelopment. Furthermore it is not known if this will contribute to a faster realisation of the EHS. To investigate the possibilities the project "Realisatie van de EHS vraagt ruimte. Van knelpunten naar kansen" (Realisation of the EHS requires space. From bottlenecks to opportunities) was started. The SKB (Foundation for Knowledge development and knowledge transfer for the Subsurface) did co-finance the project.

The project goals are:
1. contribute to the realisation of the EHS, within the set time and budget;
2. stimulate valuable use of former landfills in rural areas.

The results of the project are documented in this report. The report forms a guideline which can be used to fit former landfills within the EHS. The guideline can be applied broader. It can also be used to assign former landfills a sustainable environmental role, recreational function or a scenic function. This is also applicable to (diffuse) contaminated sites which have a low quality function at present.

The Tespellaan landfill in Noordwijkerhout was selected as test site for the project (see figure 1). This former landfill is situated within a planned ecological conduit between the 'De Keukenhof' estate and the Amsterdam Water Supply Dunes. Experiences gained in the project form the basis for the guidelines.

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Figure 1 Landfill Tespellaan situated within the bulb fields in full bloom

To realise sustainable environmental function, recreational function or a scenic function for a former landfill or a contaminated site, it is essential that the measures receive broad public support. To achieve sufficient support a planning process needs to be completed from start to finish. The planning process is a tool to:

- achieve acceptance for the proposed measures by all stake holders;
- develop to an effective solution.

A inventory of the occurring processes forms the start of the planning process. Goals for this phase are to achieve insight in:

- the relevant stake holders;
- the involvement of the stake holders;
- the interpretation of the problems by the stake holders;
- the ideal results according for each of the stake holders;
- the field of influence in which the stake holders play a role.

The actual support is assessed based on the results of the inventory. The assessment determines how to proceed with the project.

To determine whether the desired function can be assigned to the selected site, the technical potential for redevelopment needs to be assessed. For this assessment an inventory is needed of all potential technical aspects and procedures related to the redevelopment. The technical aspects and procedures can be categorised in the following frameworks:

- Environmental Framework
  Several environmental issues could play a role when transforming a landfill into a integral part of the EHS. An inventory is made when the following legislative issues are relevant: "Wet Bodembescherming" (Soil conservation act), "Wettelijke Nazorgregeling Stortplaatsen", and the "Wet Milieubeheer" (Environmental conservation Act).

- Civil Engineering Framework
  A landfills often need redevelopment prior to functional incorporation within the EHS. Several aspects of the redevelopment are relevant. Possible relevant issue are the applicable slopes, the top sealing and bottom lining of the landfill, etc. All relevant civil engineering aspects and constrains are investigated.

- Legal Framework
  Various legislative issues are applicable during redevelopment of landfill sites. When the various legislative issues are applicable is investigated. The applicable laws are: spacial planning, property law, and environmental law.

- Environmental Framework
  Assigning a natural/scenic function to a landfill, so it can function within the EHS, sets requirements to the finishing of the landfill. The conditions at the landfill must facilitate the flora and fauna to bridge the often unsuitable land between two nature reserves. An inventory is conducted to assess the requirements for the finishing by the flora and fauna.

- Regional Framework
  An inventory is conducted to determine which plans, and studies are relevant to fit a former landfill in the EHS.

The inventory lead to flow charts and "questions of research". Both are needed to determine the technical redevelopment potential swift and efficiently. Of course the development potential for the location is strongly depending on the financial feasibility. The financial feasibility itself is strongly depending on the site specific conditions like size, redevelopment and stake holders. The financial feasibility needs to be determined for every site.

When the site has the technical and procedural potential for redevelopment, sufficient social support (or this can be achieved), a set of requirements needs to be drawn up. These requirements will always contain site specific technical and procedural constraints and desires that need to be realised to maintain or acquire sufficient support. Based on the set of requirements possible options can be formulated and designed for redevelopment of the site. Next, the options can be compared according to the following criteria:
- technical size and feasibility (Is the selected option technically feasible?);
- Environmental aspects (The extent to which the option fulfils the remedial target);
- social and moral aspects (To which extent does the option lead to disturbances in the vicinity?);
- Natural value (The extent to which the option fulfils the ecological goals.);
- Costs (What is the costs-benefit ratio?).

The optimal combination of possible options will be elaborated within the operational plan. In the operational plan, the remedial activities and the redevelopment activities are described integrally. The operational plan must meet with the requirements set by the authorities in respect to remedial plans. The process to develop this operational plan is visualised below. Because this development is an interactive process in which all stake holders take part, support during the implementation is assured.

Based on their limited size, former landfills which are situated within the EHS, can only contribute little to the totally required area for a sustainable EHS. In spite of this, the conclusion of the project is that the effect of these landfills is significant. Especially when the EHS needs to be realised within the set time and costs. The functional change of the former landfill forms a catalyst for the realisation of the ecological conduit in which the landfill is situated. Reasons for this are:
- Increase of the available agricultural area. Involving land owner and attempting to minimise the claims on agricultural land, reduces the resistance. Even acquisition of agricultural land becomes optional.
- Increase of financial power. The integral approach leads to cost reduction during the construction of the ecological conduit. These saved finances can be used for the acquisition of farmland.
- Improved interaction between stake holder. Acquisition of farmland is not issue by redevelopment of a former landfill. Therefore all stake holders feel they are in a "safe area", and self-interest is no issue. Therefore better communication and better understanding between the stake holders is possible.

Next to the opportunity to co-operate, the project showed that resistances, prejudices and misunderstanding among the stake holders could be put aside. This formed an important foundation for the construction of an ecological conduit with regional support.

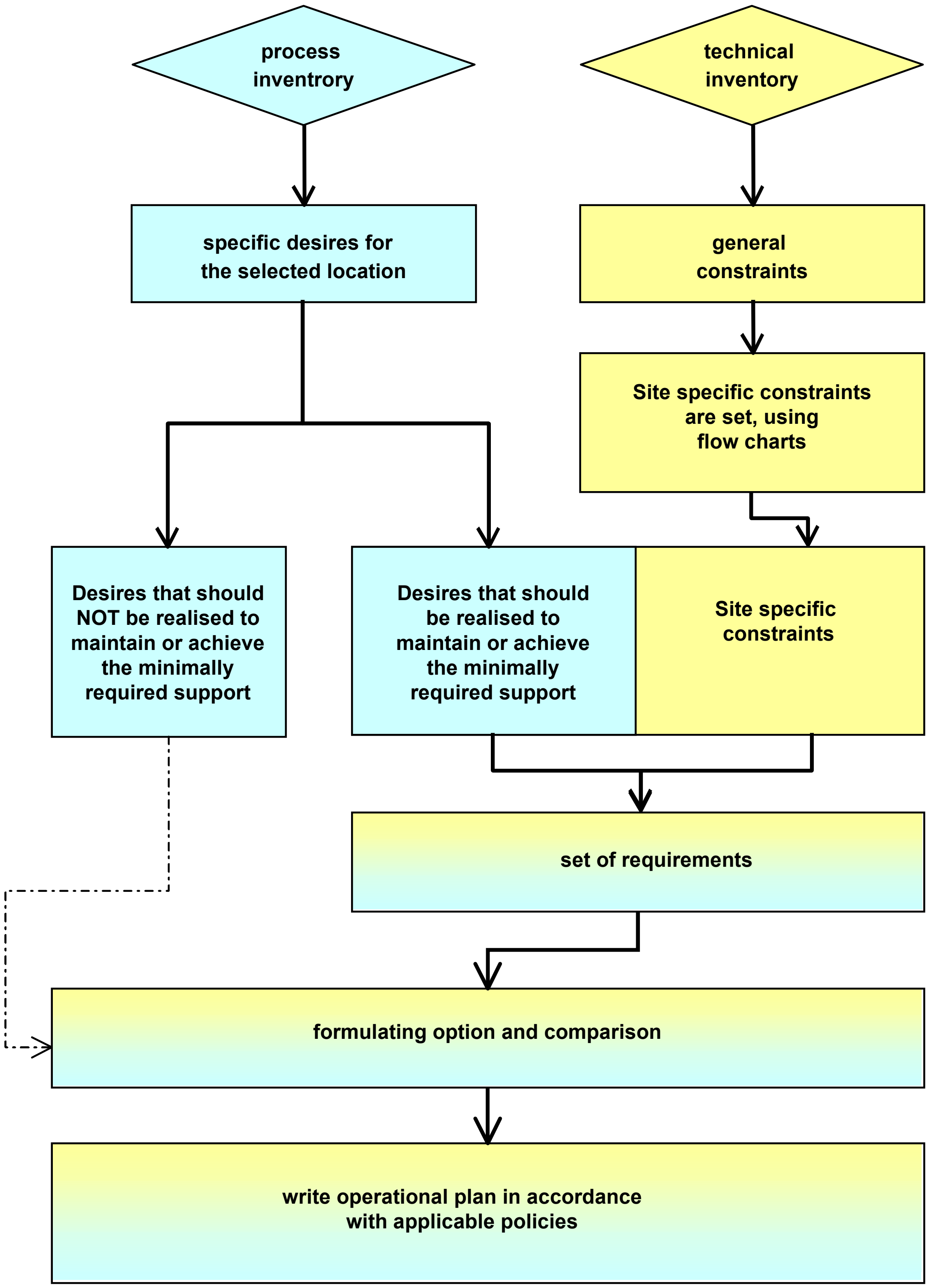

Figure 2 Visualisation of the planning process.

MANAGEMENT OF LAND CONTAMINATION: THE UK RISK BASED FRAMEWORK

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ABSTRACT

The UK government has established a legal and policy framework to ensure that appropriate action is taken when dealing with land contamination where it poses unacceptable risks to human health and the environment [1,2]. This relies on a risk based approach for identifying and managing contaminated areas of land. The Model Procedures for the management of land contamination have been developed to provide a structured risk based framework [3]. These procedures are being developed as a 2 volume document. The first volume describes the risk assessment and risk management approach, whilst volume 2 provides supporting information in the form of information boxes and worked examples.

These procedures are currently being revised and are expected to be published as a joint DEFRA (Department for Environment, Food and Rural Affairs) and Environment Agency publication in Autumn 2003.

INTRODUCTION

Land contamination in the UK is a legacy arising from previous industrial activities and operational practices in which various polluting noxious and toxic substances escaped into the environment. Previously published estimates of the extent of land affected by contamination vary widely, from 50,000 to 300,000 hectares, amounting to approximately 100,000 sites. The Environment Agency estimate, that of these, 5,000 to 20,000 may be expected to be problem sites [1, 2]. These will require action to ensure that they do not pose unacceptable risks to human health or the environment. The UK has established a policy and legal framework aimed at ensuring appropriate action is taken to deal with existing contamination where it poses unacceptable risks to human health and the environment [1, 3]. This relies on a risk based approach for identifying and managing land contamination.

The aim of this paper is to present an overview of a structured approach for informing decisions about, and taking action on land contamination. This approach is being developed as the Model Procedures for the Management of Land Contamination [4]. Development of the Model Procedures has incorporated good technical practice in risk assessment and risk management, into a systematic process for identifying, making decisions about and taking appropriate action to deal with contamination in a way that is consistent with UK policy and legislation.

These procedures are relevant to all situations where land contamination may exist, for example in connection with site redevelopment under the Planning regime, or Part IIA of the Environmental Protection Act 1990. They will be available for use by all parties involved with, or interested in land contamination including; site owners and occupiers, environmental consultancies, regulators, lawyers, financiers and insurers.

Key principles of the Model Procedures

The Model Procedures provide a generic framework for using a risk based approach when dealing with individual areas of land contamination or portfolios of sites (Figure 1). This framework consists of three primary components:

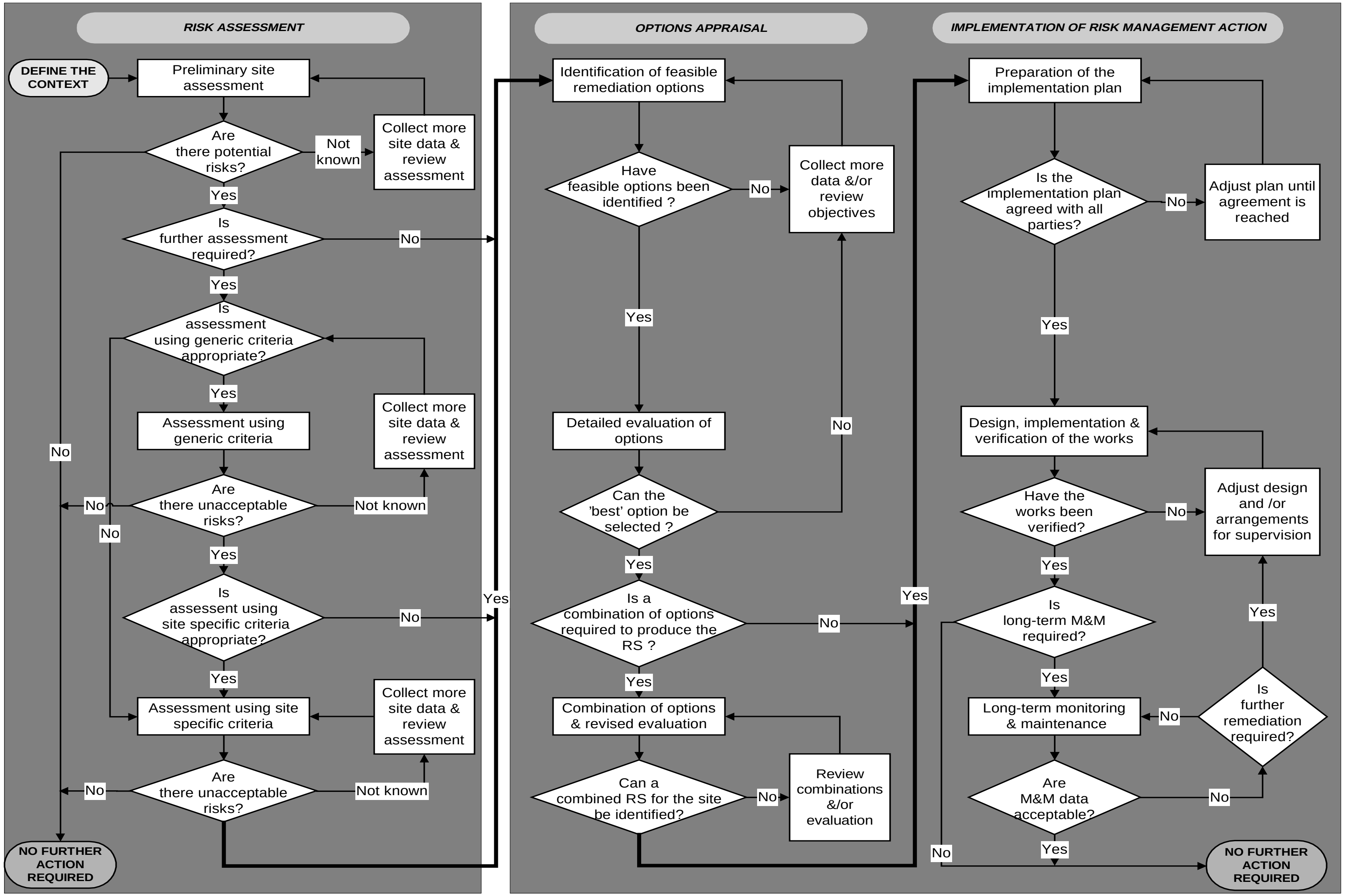
- Risk assessment: – to establish whether unacceptable risks exist, and if so, what further action should be taken in relation to the site;

- Risk management – options appraisal: - where it is necessary to remediate, evaluate feasible remedial options and determine the most appropriate remediation strategy for the site;

- Risk management – implementation of the selected remediation strategy and demonstration that it is, and will continue to be effective.

This framework illustrates a phased process with scope for iteration within individual components.

It shows that a risk based approach for the management of land contamination should offer flexibility in terms of the possible response options for a particular set of conditions. For example, once a problem has been identified and understood, the process should allow managers to move quickly to options appraisal and remediation, rather than directing them to ever more detailed risk assessment to further demonstrate that the problem exists.



Key

RS = Remediation Strategy

M&M = Monitoring & maintenance

Figure 1. Risk management framework for dealing with land contamination

Risk Assessment

Risk assessment provides a structured mechanism for identifying potential problems across a range of activities and making judgements about their consequences. Assessing risks from land contamination underpins the "suitable for use" approach and is built into the definition of contaminated land under Part IIA of the Environmental Protection Act 1990. The aim is to decide whether there are unacceptable risks to people or to the wider environment. Risks in terms of land contamination have three key elements;

- contaminant – a substance present on the land which has the potential to cause harm to human health or the wider environment, or to damage property;
- receptor – an entity, such as human occupants of the site, an ecological system or a water body, that could be adversely affected; and
- pathway – a means by which a receptor can be exposed to, or affected by, a contaminant.

Each of these elements can exist independently, but they create a risk only where they are linked together – so that a particular contaminant affects a particular receptor through a particular pathway. This linked combination of "contaminant-pathway-receptor" has been given the label of a "pollutant linkage".

On any individual site, there may only be a single pollutant linkage or there may be several. Different pollutant linkages may be related – for example, the same contaminant may be linked to two or more distinct types of receptor by different pathways. But each pollutant linkage will create a different "risk" that needs to be separately identified, understood and managed.

The risk assessment approach adopted broadly fits within an overall tiered process, that requires an increasing level of detail in progressing through the tiers. The three tiers, or stages, are:

1 Preliminary risk assessment

2 Risk assessment using generic site criteria and assumptions

3 Risk assessment using specific site criteria and assumptions

Once the need for risk assessment has been identified, it will always be necessary to go through the preliminary risk assessment stage and develop a site conceptual model which supports the identification and assessment of pollutant linkages. However, depending on the circumstances, it may not be necessary to do a more detailed generic and/or site specific risk assessment.

Once the risks are assessed, the next part of the process is the appraisal of options for risk management actions to deal with the risks, followed by implementation of an appropriate action. Figure 2 illustrates the relationship between risk assessment and the later stages, and the key decisions in risk assessment that contribute to the overall management process.

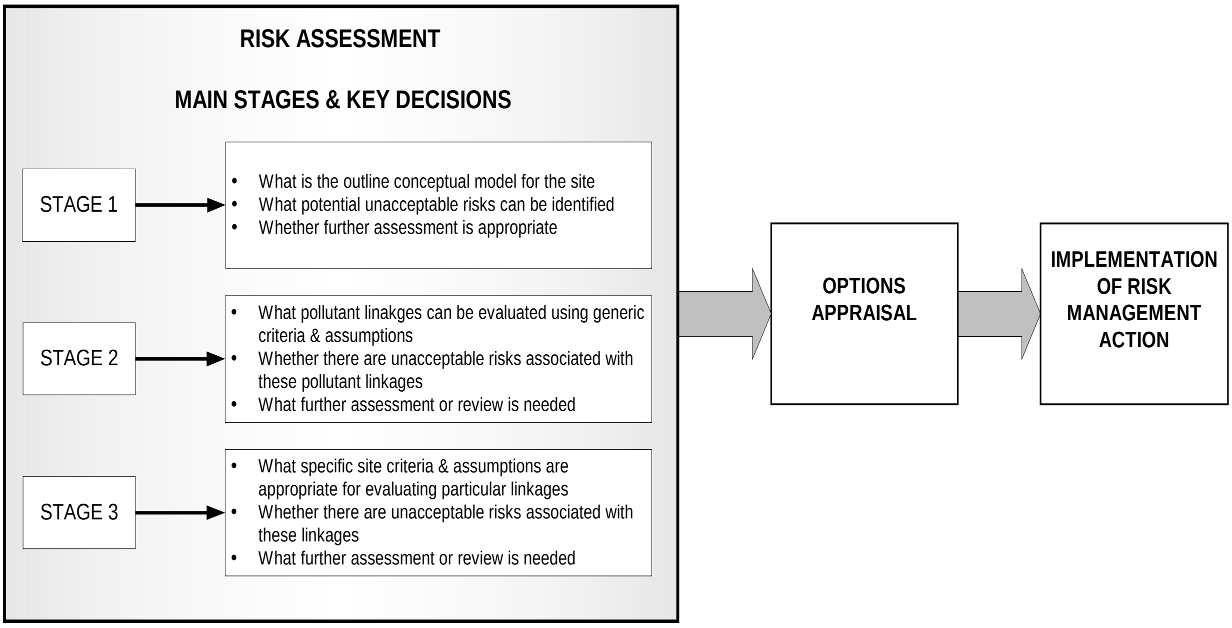


Figure 2. Main stages in risk assessment

Risk Management - Options Appraisal

Options appraisal is the first stage of risk management. It comes into play only if risk assessment demonstrates that there are unacceptable human health or environmental risks associated with a site.

In practice there may be a number of a ways of reducing or controlling unacceptable risks all of which will have advantages and limitations in any particular case. The role of options appraisal is to establish, taking all the circumstances of the site into account, which option (either singly or in combination) offersthe best remedial solution for the site as a whole.

There are three main stages of options appraisal:

1 Identifying feasible remediation options for each relevant pollutant linkage

2 Carrying out a structured evaluation of feasible remediation options to identify the ‘best’ option for any particular linkage

3. Where appropriate, combining options to produce a remediation strategy that will address all relevant pollutant linkages

Figure 3 sets out the key decisions at each stage, and the relationship between options appraisal and the processes of risk assessment and implementation of risk management action.

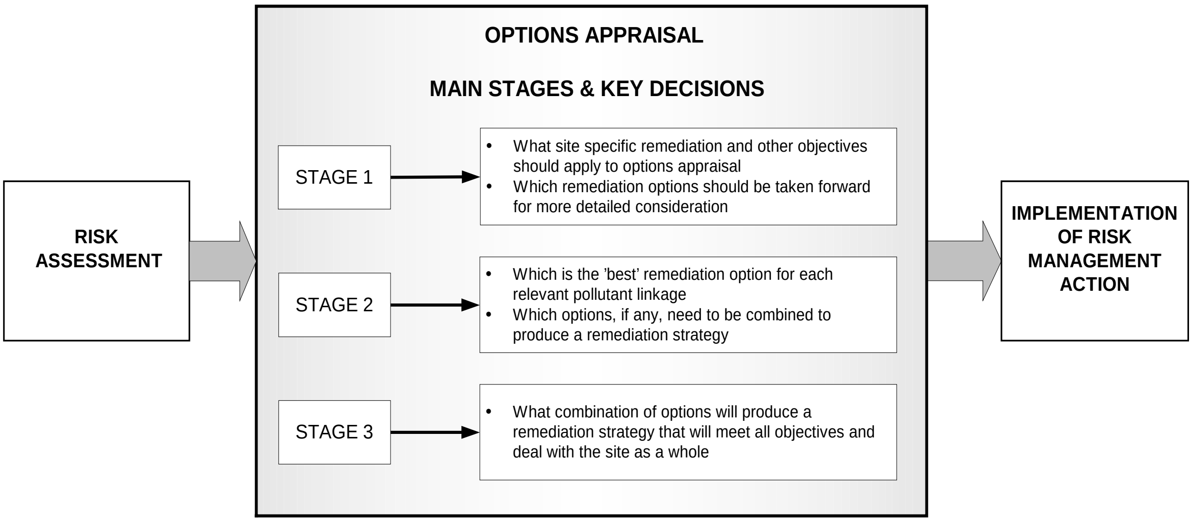


Figure 3. Main stages when evaluating and selecting risk management options

Risk management – implementation

Having defined the need for, and scope of, remediation necessary to deal with all relevant pollutant linkages, a remediation strategy must be implemented. This may involve carrying out the works as an independent project or combining them with any other works planned for the site. For example, if the site is being redeveloped, then the remediation strategy may need to be combined with foundation work or earthworks to achieve necessary development platform levels. By contrast, where the work is being carried out solely to deal with a pollution problem, then the remediation strategy need address only this single issue. An implementation plan needs to be drawn up which deals with all aspects of design, preparation, implementation, verification, long-term maintenance and monitoring of the remedial works.

The works may be implemented as a standalone contract or as an integral part of any development-related or other infrastructure project. Implementation of the strategy must be fully recorded, such that there is a permanent record (the verification report) of the works and its effectiveness. Where necessary, the works should be monitored and maintained. Monitoring may be used as a means of demonstrating compliance against predicted behaviour and as an early warning of adverse trends.

There are three main stages in the implementation process:

1 Preparing the implementation plan

2 Design, implementation and verification of the works

3 Post-contract long term monitoring and maintenance

Figure 4 illustrates the key decisions at each stage and the relationship between implementation and the earlier processes of risk assessment and options appraisal.

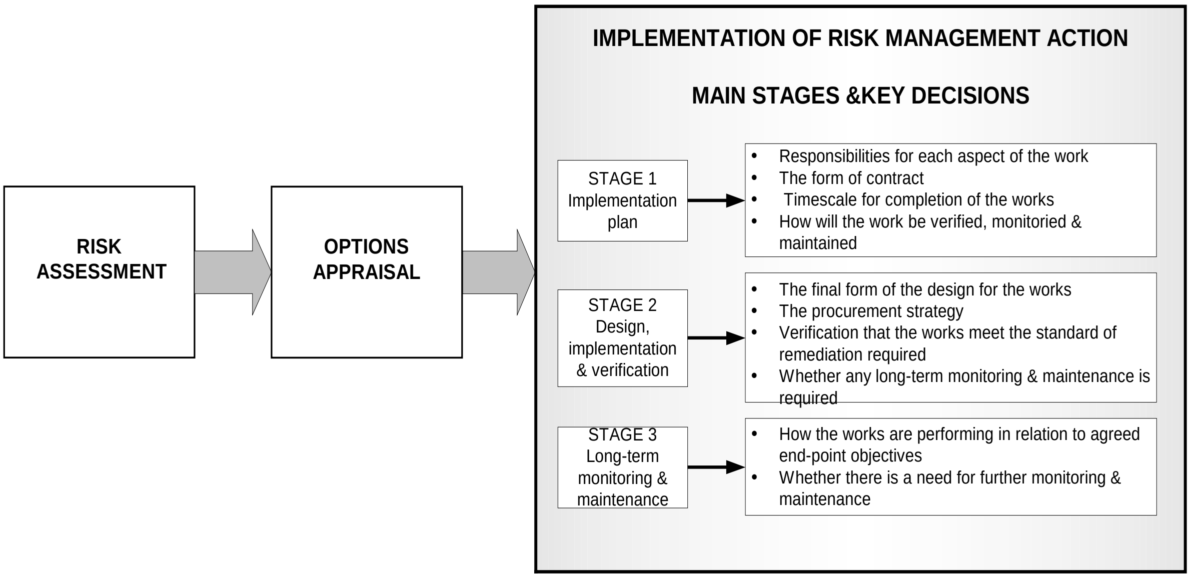


Figure 4. Main stages in implementing risk management actions

Conclusions

Land is affected by contamination because historical industrial practices have led to the deliberate or accidental release or disposal of substances onto land. In the UK, a risk based framework is taken to manage land contaminated on a site specific basis. This framework provides a technical basis to collate suitable data for informing decisions concerning land contamination at each stage, i.e. risk assessment; appraisal of remedial options and implementation. It is intended that this will encourage and improve current practice in managing areas of land contamination among technical professionals.

REFERENCES

[1] Department of the Environment, Transport and the Regions (2000). *Environmental Protection Act 1990. Part IIA Contaminated Land*. DETR Circular 02/2000.

[2] Environment Agency (2002) Dealing with contaminated land in England: Progress in 2002 with implemnting the Part IIA regime. The Environment Agency, Rio House, Bristol, UK. ISBN 1857059581

[3] Department for Environment, Food and Rural Affairs, Environment Agency and the Institute for Environment and Health (2000). *Guidelines for environmental risk assessment and management*. The Stationery Office.

[4] Department for Environment, Food and Rural Affairs and Environment Agency (in preparation). *Model Procedures for the Management of Land Contamination*. Prepared under contract P5-083 by Casella Stanger, Birmingham, UK.

[5] Department for Environment, Food and Rural Affairs (2002). *Assessment of risks to human health from land contamination: an overview of the development of Soil Guideline Values and related research. R&D Publication CLR7*. Available to download from www.defra.gov.uk

[6] Environment Agency (1999). *Methodology for the derivation of remedial targets for soil and groundwater to protect water resources*. Environment Agency R&D Publication 20. Bristol.

POTENTIALLY EXPLOTATION OF DEGRADED ENTISOL THROUGH CROP DIVERSIFICATION

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Bastar Plateau Zone belongs to the Eastern hill and plateau agro-climatic zone of India. It is situated between $17^0$45'to $20^0$34' North latitude and $80^0$15' to 82^0East longitude with altitude ranging from 550-760 m above mean sea levels. It has complete land locked geographical area of 39.114 thousand square kilometers. Total cultivated area is around 8.8 million hectare of which more than 50 per cent are entisols. Minor millets and short duration rice varieties are being cultivated on these soils without application of organic matter and chemical fertilizers resulted the degradation in available inherant capacity of fertility status of these soils. Hence there is an urgent need to improve the inherent fertility and check erosion in sloppy land through crop diversification.

The agro-climatic conditions are very well suited for the cultivation of Niger (*Guizotia abyssinica* (L.F.) Cass), Castor (*Ricinus communis* L.) and Horsegram (*Macrotyloma biflorus* L.) on the entisols during mid rainy season. Presently, Niger is being grown in the area of 30 thousand hactaers with the mean seed yield of 205 kg/ha by using the local land varieties, whereas castor is an introducing crop in this region. Hence there is need for identification high yielding varieties for better productivity in entisols. Among the Niger varieties, GA-5 recorded the highest seed yield of 314 kg/ha followed by Oottcamound (307 kg/ha) and GA-10 (297 kg/ha) (Table-1). These varieties were recorded more than 30 percent yield increase over the local cultivars. To popularize cultivation of high yielding Niger varieties, front line demonstrations were conducted in the large area under entisols. In the target environment, variety GA-10 performed the yield potential of 650 kg/ha with the recommended package of practices for cultivation of Niger (Table-2). Ten Horsegram varieties had the mean seed yield of 337 kg/ha over the locations (Table-3). A high yielding variety from the local collection SK-2001 (442 kg/ha) exhibited highest mean seed yield followed by Bastar White (429 kg/ha) and Bastar Black (385 kg/ha).This indicated that the local varieties of prevailing in region had good yield potential. But these local varieties are late maturing type which fail to perform well under drought conditions, so the early maturing variety will suited for the risk free higher productivity to exploit entisols. An early maturing variety Ak-21 was demonstrated in target environment, which showed the yield potential of 540 kg/ha (Table-2).

Castor cultivation during the rainy seasons posses the many pest and disease problems, but well fitted in mid rainy seasons with higher productivity. The mean seed yields were 331 and 321 kg/ha in the year 1995 and 1996, respectively, when sown in the July month. The poor yield was due to thin plant population due to wilt incidence and heavy attack of castor semilooper during peak vegetative growth. Moreover, the primary spikes matured during rainy days hence, the crop was attacked by gray rot and capsule borer. Looking in to the pest and insect incidences the sowing dates were shifted to September in 1997, but this year was drought year and the mean seed yield was only 283 kg/ha. Hundred seed weight was high in 1995 (23.76 g) and 1996 (20.85 g) as compared to 1997 (18.77 g). The poor yield and lowest seed weight was due to water stress, but the biotic stresses were very less as compared to the July sowing. Keeping in view the past experiences the varietal trial was sown in September during 2001. Good amount of rains were received during the crop growth season and coupled with least incidence of pests and diseases, the mean yield potential of 1635 kg/ha was obtained in Bastar. Hundred seed weight was also highest (30.08 g) in this year due to the favourable crop growing conditions. Similarly, the yield levels at Chhattisgarh Plains Zone were also better in September sown (1947 kg/ha) with higher 100 seed weight (30.5 g) as compared to August sown crop (1635 kg/ha and 28.06 g 100 seed weight).

Castor and Niger are the tap rooted crops having the potential to check the soil erosion of sloppy land however Horsegram is legume crop, which add the nitrogen in these soils. Moreover these crops are monocarpic senescence in nature, which additionally improve the soil fertility by adding the organic matter. Ultimately, the study showed that under sustainable agricultural practices, entisols might be exploited efficiently through suitable crop diversity, which will also improve the soil fertility and quality.

Table-1 Performance of Niger varieties over the years in entisols of Bastar.

Variety	Days to Maturity				Plant Height (cm)				Seed Yield (kg/ha.)			
	2000	2001	2001*	Mean	2000	2001	2001*	Mean	2000	2001	2001*	Mean
GA-5	93	93	98	95	60	74	78	71	1.31	2.60	5.51	3.14
GA-10	86	93	96	92	77	85	95	86	1.53	2.65	4.72	2.91
Ootacamund	90	91	94	92	73	63	78	71	1.34	2.76	5.10	3.07
IGP-76	86	91	89	89	73	65	72	70	1.59	1.98	3.49	2.35
Local-11	94	93	97	95	69	65	68	67	1.85	1.86	3.03	2.25
							Mean		1.53	2.37	4.38	2.74
							CD at 5 %		0.29	0.21	0.16	

* Experiments in Farmers Field

Table-2 Front line demonstrations on Niger and Horse Gram in entisols during 2001

Crop	Variety	No. of demonstrations	Seed Yield Kg/ha				% Improvement
			Improved Method Mean	Local Practice Mean	Maximum	Minimum	
Horse Gram	AK-21	04	5.4	3.8	6.7	4.5	14.21
Niger	GA-10	20	650	430	750	564	51.16

Table-3 Performance of Horesegram Varieties over the years

Variety	Days to Maturity			Plant Height (cm)			Seed Yield (kg/ha.)		
	2001	2001*	Mean	2001	2001*	Mean	2001	2001*	Mean
Birsa Kulthi	72	74	73	22.1	30.2	26.15	2.44	3.00	2.72
BGM-1	119	116	117.5	23.7	28.6	26.15	3.51	3.78	3.65
Maru Kulthi	73	83	78	22.5	24.5	23.5	3.25	2.81	3.03
VL Gehat-1	73	73	73	20.1	23.8	21.95	3.07	3.00	3.04
PHG-9	110	105	107.5	34.4	38.5	36.45	4.33	3.96	4.15
AK-21	75	78	76.5	22.0	25.2	23.6	3.33	3.44	3.39
Bastar Black	104	108	106	25.5	28.0	26.75	3.55	3.44	3.5
Bastar White	87	84	85.5	20.2	25.4	22.8	4.14	4.44	4.29
SK-2001	127	123	125	27.6	31.0	29.3	4.44	4.40	4.42
HPK-4	71	74	72.5	22.0	26.6	24.3	1.11	1.89	1.5
						Mean	3.30	3.40	3.37
						CD at 5%	0.58	0.33	

* Experiments in Farmers Field

Table-4 Seed yield and 100 seed weight of castor varieties/hybrids over the years in Entisoils of Chhattisgarh state.

Variety/ Hybrid	Seed yield (kg/ha.)					
	1995	1996	1997	2001	2001	2001
	July sown (Jagdapur)	July sown (Jagdapur)	Sept. sown (Jagdapur)	Sept. sown (Jagdapur)	Sept. sown (Raipur)	Aug. sown (Raipur)
DCS-9	322	548	290	1517	-	1278
Aruna	226	243	327	-	-	-
48-1	-	157	-	1462	1724	-
GCH-4	446	576	320	1853	2191	1880
GCH-5	-	429	-	1730	1926	-
DCH-32	-	297	195	1617	-	1748
Mean	331	321	283	1635	1947	1635
	100 seed weight (grams)					
DCS-9	23.1	20.7	20.3	27.2	-	26.1
Aruna	23.7	14.4	16.5	-	-	-
48-1	-	22.1	-	33.1	29.7	-
GCH-4	24.5	23.7	18.3	29.7	30.3	29.7
GCH-5	-	23.5	-	32.5	31.5	-
DCH-32	-	20.7	20.0	27.9	-	28.4
Mean	23.76	20.85	18.77	30.08	30.5	28.06

URBSOIL: DEVELOPING DECISION SUPPORT TOOLS TO EVALUATE THE ROLE OF SOIL QUALITY IN SUSTAINABLE URBAN MANAGEMENT

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1. Introduction

The importance of achieving sustainable development and developing the environmental agenda at the European level is likely to have significant impact on the planning system (Chapman 1999). The World Commission on Environment and Development (1987), commonly known as the 'Brundtland Report', defined sustainable development as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*."

Applying the principles of sustainable development will require "a strong emphasis on compact, multi-purpose urban settlements in order to increase local availability of essential services, reduce the need to travel and provide more energy-efficient transport systems, while also reducing further loss or rural land to urban development" (DoE 1996). One-way to achieve this is through the re-use and recycling of previously developed (brownfield) land. The dominant influence on soil quality of brownfield sites has been previous land uses and, because urban soils are often developed on composite materials, derived from previous uses and exogenous sources, spatial heterogeneity is a typical feature (De Kimp 2000).

In March 1992, the European Community (EC) adopted the fifth of its environmental action programmes designed to protect and enhance the quality of the environment within the European Union (EU). Based on the thesis of 'sustainable development', the strategy recognises that environmental damage will never be halted unless behavioural patterns of producers and consumers, governments and citizens are altered to take the environment into account (Chapman 1999). One project commissioned as part of the EU's fifth framework programme is URBSOIL (http://urbsoil.paisley.ac.uk).

URBSOIL is an acronym for:

Urban Soils as a Source or Sink for Pollution: Towards a Common European Methodology for the Evaluation of their Environmental Quality as a Tool for Sustainable Urban Management

URBSOIL is a network of seven research groups from five different cities/countries throughout the EU. Reflecting as wide a geographical and climatic variation as possible, they are Uppsala (Sweden), Aveiro (Portugal), Sevilla (Spain), Glasgow (UK), Torino (Italy) and Ljubjana (Slovenia). This paper concerns the development of a spatial decision support system for sustainable urban development, as part of a PhD programme within the URBSOIL network.

Spatial decision support systems consider situations where complex spatial problems are ill defined or semi-structured and where decision makers cannot define their problem or fully articulate objectives (Ascough II et al 2002, Zhang & Day 2002, URISA 2002). Multicriteria-spatial decision support systems (MC-SDSS) improve this process by providing a flexible problem-solving environment where the user is free to explore, understand and redefine a problem. In addition, any user should be able to investigate trade-offs between multiple and conflicting objectives and set priorities accordingly.

Further, MC-SDSS should provide support for both single users and group decision processes and should not exclude stakeholders.

This paper presents a foundation framework that focuses on the problems of urban soils and the role respective stakeholders have in its management/use. It also relates to degree of difficulty encountered when multiple sources of relevant data are available yet liasing with many stakeholders involved in environmental decision-making has revealed that sensitive information is preciously guarded despite legal requirements for transparency (NSCA 2002).

Thus, decision aids developed by URBSOIL will have to rely on data and information initially generated solely by the URBSOIL network. However, as it is known that data that can enhance the decision process is available, e.g. previous land use via contaminated land registers (NSCA 2002). URBSOIL MC-SDSS development should also embrace a flexibility where the ability to input additional data can also be supported.

Predominantly at the heart of suitable MC-SDSS is a Geographic Information System (GIS) (Ascough II et al 2002). This paper first outlines available GIS technologies and then the direction of development that can achieve optimum returns for objectives described above.

2. GIS and Decision Support

There are many examples in the literature where decision support tools have been developed around stand-alone computer based GIS products. However, these add-on software components, by their nature, can only be utilised by endusers who have access to the parent GIS software. As an example, GeoChoicePerspectives is a non Internet based ArcView extension (Geochoice 1996). This means it can only be utilised by an enduser who has access to ArcView software. Thus, it is highly probable that the use of stand-alone add-on components, such as GeoChoicePerspectives, to aid a particular decision will exclude, potentially highly valuable, stakeholders.

Web-based GIS decision support tool development has many advantages (Pandy 2002; Carver 1996). It provides opportunities to increase involvement of stakeholders in the decision-making and planning process by providing knowledge and data through a widely accessible, fast, cost-effective, and easy-to-use medium. The application can be accessed from a Web-based component and displayed in a browser. The basic architecture of Web-based GIS is shown in Figure 1.

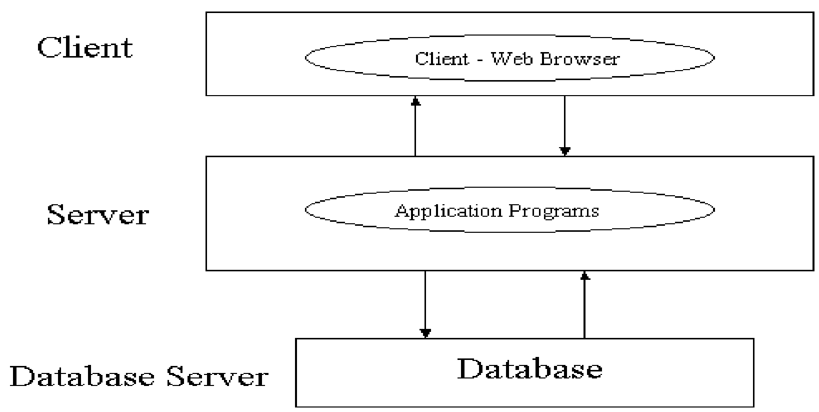

***Figure 1**: A Summary Of Web-GIS Architecture (Adapted From Zhang & Day 2002; Jiang Et Al 2002)*

The client is essentially a Web browser running on any computer that has access to the World Wide Web, for example Microsoft's Internet Explorer or Netscape. The browser serves as an interface between the user and the GIS. The application server is the functional modules that process data, perform complex analysis and calculations, and allows communication between the client and the GIS, also stored here. The final tier is a database management system (DBMS) that stores and manipulates the data to be used by the application server.

3. Urban Soil Mapping

Urban soil parameters can be separated and considered as a combination of background 'natural' conditions and anthropogenic impact (Asante-Duah 1998; Miko et al 1999; Birke & Rauch 2000).

3.1 Background Conditions

Background conditions of urban soil are those values that "*distinguish site-related contamination from naturally occurring or other non-site related levels of select constituents*" (Asante-Duah 1998). The background population is a "*complex combination of natural soil, widespread anthropogenic, spatially-correlated anthropogenic, and stratified random anthropogenic populations*" (Fokes & Kuehster 2001). It is possible to estimate regional background conditions using geostatistical techniques (Asante-Duah 1998; Miko et al 1999; Birke & Rauch 2000). Whilst this has been widely applied to elemental concentrations, little attention has been paid to parameters, which may define soil quality.

Given that, within an urban environment, the soil conditions are expected to be highly variable due to high levels of anthropogenic impact and that the resources within URBSOIL only allow for the collection of samples to represent a small portion of each city, it is to be expected that the degree of uncertainty of certain soil parameters will be very high.

The higher the levels of uncertainty of soil parameters, the lower the confidence end-users can have for estimates of soil parameter values. However, given that currently no regional background soil maps exist for any of the cities in the URBSOIL network, any regional map that can be generated by URBSOIL has to be an improvement. Indeed, it is precisely because of the uncertainties within this problem that a regional map is beneficial to an end-user. As van Buerden and Padding (1994) state, "*it may very well be useless to the decision maker to see uncertainties in a table, but it may be different when uncertainties have spatial variations*".

3.2 Anthropogenic Impacts

Ideally, models of anthropogenic (human) impact must be able to represent spatial and temporal dimensions of parameters that take into account, not only the additive effects of anthropogenic input, but also the combined effects, positive and negative, that may result from such input (Asante-Duah 1998). Quantitative estimations of anthropogenic input are, by definition, numerical calculations. With an appropriate user interface, numerical estimations of the parameters involved in the model equation can be entered into the decision support framework.

3.3 Delphi Consensus

It has been shown that GIS can display effectively complex soil data. It can analyse and utilise models to highlight to stakeholders the results of certain actions. Systems like these tend to be very logical, providing hard facts or findings on soil processes. Unfortunately, they no longer satisfy stakeholders (Feick & Hall 1999).

Stakeholders will be untrusting of URBSOIL if a system is developed that, in effect, provides answers for them. Stakeholders want access to the processes of how results were derived. They wish to consider the assumptions that were made by the URBSOIL science experts. They desire the ability to change criteria and other assumptions to derive their own value for soil parcels within their jurisdiction. In this way, model values do not attempt to eliminate bias, but rather every stakeholders' personal bias can be incorporated into the decision discourse. A crude analogy would be a hard line environmentalist estimating the impact of some future development resulting in contamination where a purely profit based developer could provide an estimate, from the model, that the land parcel would be within safe limits.

By presenting these derived soil parcel values to all the other stakeholders within the group, an iterative discourse can begin. This method of iterative discourse is not unlike the Delphi method (Martino 1972; Turoff & Hiltz 1996) where a series of rounds can either highlight consensus or disagreement amongst stakeholders. An ability to achieve a consensus can thus provide an 'acceptable' estimate of site specific soil conditions which satisfies most, if not all, stakeholders.

It is possible to generate, via a computer, a prepared report that can be sent to either a discussion forum or back to a system administrator. Indeed, this is seen as desirable for next generation MC-SDSS (Asgough II et al 2002). The computer-generated report should outline the derived values by the end-user utilizing the MC-SDSS. It should also highlight assumptions that were used to obtain these values and comments justifying those assumptions.

A method such as this would require high level programming but should not be beyond the limits of an experienced programmer.

3.4 Summary of Map Generation

This section has outlined the first level of decision support. That is, from a regional map of a city, a polygon can be selected and a models run within it. The combined regional map and polygon model can be used to give an end-user an estimation of soil conditions within that particular site. This is summarised in Figure 2.

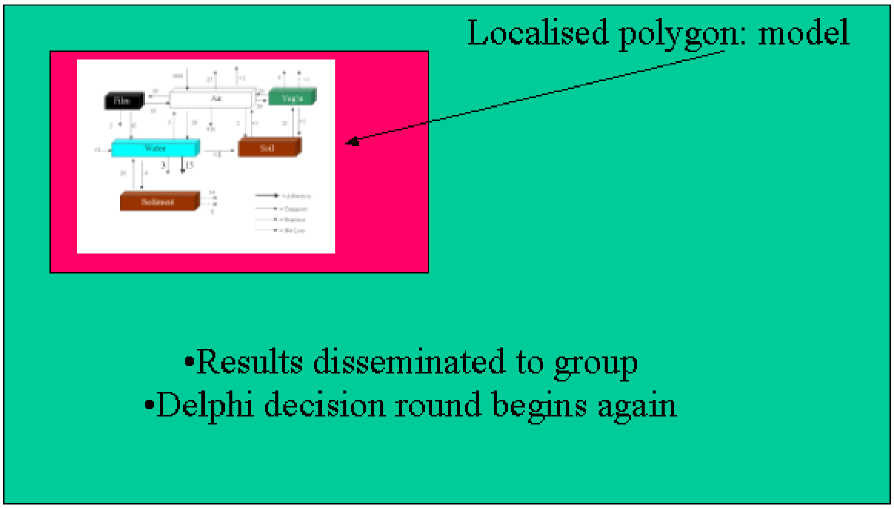

***Figure 2**: A Schematic Summary Of The Decision Support Process.*

4. Knowledge Bases

4.1 Soil Parameters

It can be expected that the probability of achieving a more accurate estimation of soil parameters and priorities would increase if end-users had access to knowledge from experts in the field to which end-users are inquiring. In this way, reasonable estimations of parameter values can be selected by stakeholders and queried by others to allow positive iterative discourse. One method of supplying knowledge involves the development of a suitable knowledge base (Turoff et al 1998). Knowledge bases, within a given field, can be developed from online forums utilised by appropriate experts. URBSOIL already has a forum in which active debate is aiding construction of a suitable knowledge base. The evolution of this area of decision support still requires much investigation, however URBSOIL's online forum can be viewed as a suitable foundation.

4.2 Remediation Processes

Another input of knowledge can be available from companies involved in the remediation process. Information of new technologies can be made available to the end-users via an online forum or a regularly updated URBSOIL Web page. Links to Web sites of companies involved in remediation strategies would allow further investigation of their products.

4.3 Summary

With the addition of the knowledge base, the decision support structure outlined in Section 3, above can now be modified to include the knowledge base. This is highlighted in Figure 3. Note also the inclusion of an online forum, briefly discussed in section 3 and 4 that can allow informal discourse between end users (Woolley 1995).

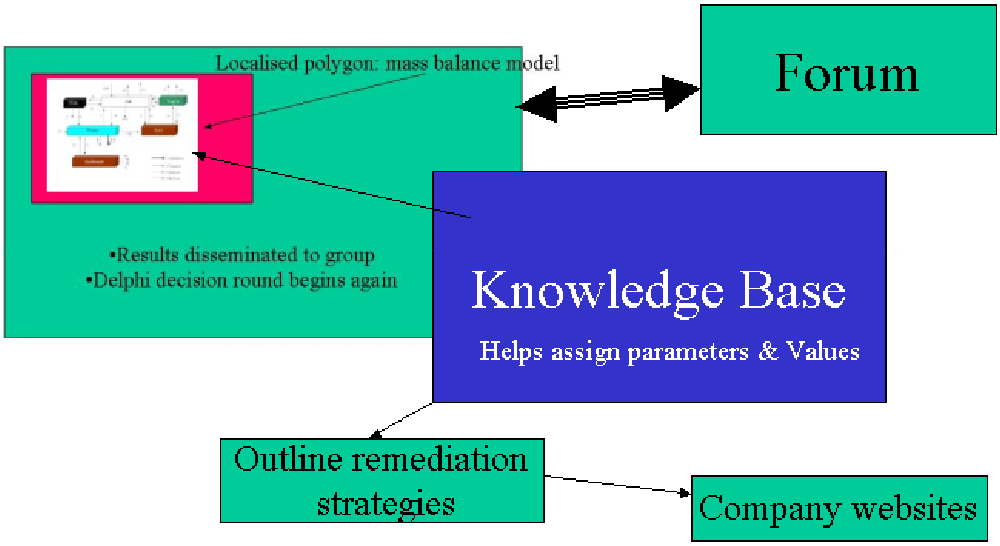

Figure 3*: A Detailed Schematic Summary Of The Decision Support System With The Inclusion Of Knowledge Base And Forum*

5. Are All Decisions Supported?

A search of the available literature highlights that environmental decision problems fall into two main categories: site appraisal and goals.

5.1 Site Appraisal

Site appraisal considers a parcel of land and its effectiveness in achieving a desired outcome. Such site appraisals consider impact or risk assessment, e.g. the impact of an urban open composting plant or wastewater sewage sludge utilisation (UNCHS 1998); and site locations, e.g. location of urban orchards (ICLE 1997) or housing stock (Asante-Duah 1998).

The foundation framework described above can aid site appraisal. For example, parcels of land can be selected for either housing stock or industrial premises (Asante-Duah 1998). There is a greater human health risk associated with housing stock, compared to industrial areas that can be sealed by concrete. Occupiers may desire gardens. They may want to grow edible plants, which may bio-accumulate toxic heavy metals (Alloway 1997) or small children in the occupier's family may adsorb heavy metals by ingestion of their garden soil. Querying an urban soil regional map should establish parcels of land available where background concentrations fall within acceptable limits for housing stock. This set of polygons (locations) can be reduced yet further by the use of models which utilise all available site-specific data. In addition, the group process, Delphi, can be utilised to locate an environmentally optimal sites. This is an example of utilising a site-specific numerical analysis for previous land use to establish an estimate of present soil quality.

With regard to the application of sewage sludge to land, once again, a regional citywide appraisal can highlight suitable locations. These locations can then be modelled, as for housing locations, to estimate present soil conditions. Finally, a numerical site-specific model simulating future sewage sludge application can be implemented to highlight sites with the greatest retaining capacity for pollutants within the sludge. Thus a site can be predicted where the greatest volume per year of sewage sludge can be applied. Once again the Delphi process can aid this appraisal to produce optimal locations.

5.2 Goals

Goals have to consider problems that have no derived measures and thus cannot utilise models to view conditions or impacts. Examples of such problems include urban greening programs; best strategy for complying with the environmental objectives implemented by the Provincial Council of Cordoba and industrial transformation and cleaner productions to achieve sustainability goals formulated in Benxi, China (UNCHS 1998). These complex environmental goal problems have to consider many criteria, many of which will vary in significance depending on the point of view of multiple stakeholders.

Multicriteria problems, such as these, can be supported by use of the Analytical Hierarchy Process (Ramanathan 2001; URISA 1994;). Developed by Saaty in the 1970s, these problems are reduced to a hierarchy of criteria, with those judged the most important first with underlying criteria supporting. This reduction enables simple pair-wise comparison of each of the criteria within its relevant hierarchy to arrive at "overall priorities for the alternatives of action".

A simple example is given in Figure 4 which reduces the goal of deciding on which house to buy to a pair-wise comparison of three criteria: price, location and age (Ramanathan 2001). The criteria are compared pair-wise to each other: price v location, location v age and age v price. Thus, categorising each criteria according to its weighting in this particular problem. For each house under consideration, the respective values are input for price, location and age. From these input values, it can be calculated the optimum house to buy according to the preferred weighting and values assigned by the user.

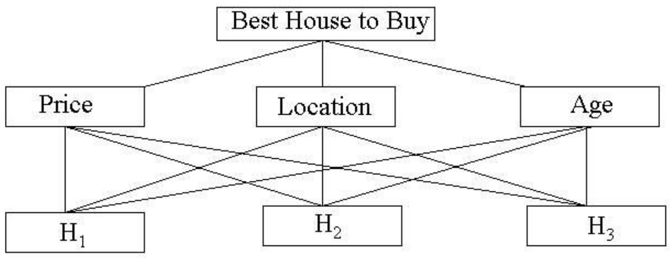

***Figure 4**: An Example Of A Goals Model. In This Case, A Representation Of AHP (Adapted From Ramanathan 2001)*

AHP is an example of a multi-criteria decision method (Ramanathan 2001). Although others exist, AHP is much cited for its flexibility and intuitiveness.

It is possible to integrate multi-criteria decision aids within a GIS environment. Ascough II et al (2002) highlight two such systems. The main problem is that systems of this nature require data to integrate criteria as overlays within a GIS. Lack of data, as indicated in the introduction, restricts development of such a system. However, the inclusion of a Web-based multi-criteria decision aid, such as Web-HIPRE, into the foundation framework provides a frame of reference for future research.

6. User Interface & Dynamic Content Generation

Essential to the interactivity of the end-user is a user interface (Ascough II et al 2002; Zhang & Day, 2002). The first important design principal, as Zhang & Day (2002) state, is that "*information should be structured in ways that allow for connection, interaction and interference*". The second is simplicity. In other words, the interface should allow input at each stage, where possible, of the decision making process and has to be of a design where decision problems are easy to comprehend and allow flexibility, within limits, of input choices. In addition, it should allow areas for comments for the end user to justify their choice of input values. Similarly, it should allow simple selection of appropriate models again with justification comment boxes.

The ability to select various models with variable, perhaps different, parameters and the ability to add comment generates a true dynamic-ness to the MC-SDSS. It involves manipulation of the database, customisation of the output and requires an automated generation of an HTML page for each query for each individual user (Thomson 2002). This requires support within the server software for scripting. The original means to support scripting was by use of the Common Gateway Interface (CGI) with programs written in a language supported by the server, such as Perl. However, the architecture of CGI is slow compared to the more recently developed compiled server-side scripts (such as Java servlets, JSP, Coldfusion and ASP.NET) as and is generally considered unsuitable for high performance and high volume websites. Compiled server-side scripts also simplify the web development process because it doesn't require high-level computer programming or server-side scripting to achieve suitably powerful applications (Thomson 2002; Brown & Frederick 2001).

7. Summary

Figure 5 presents a summary of the foundation framework being developed to support URBSOIL. Such a foundation framework satisfies the conditions of Multiciteria Spatial Decision Support Systems as outlined by Ascough II et al (2002). That is, it is a flexible system, with a user-friendly interface, and visual display, that allows each end-user the ability to think through an urban soil problem. In addition, each end-user can access a knowledge base that can aid their understanding of the issues involved. Further, the end-user presents results to the other members of the group in an iterative process and non-time-consuming manner (i.e. a computer generated report) that can aid consensus between all stakeholders.

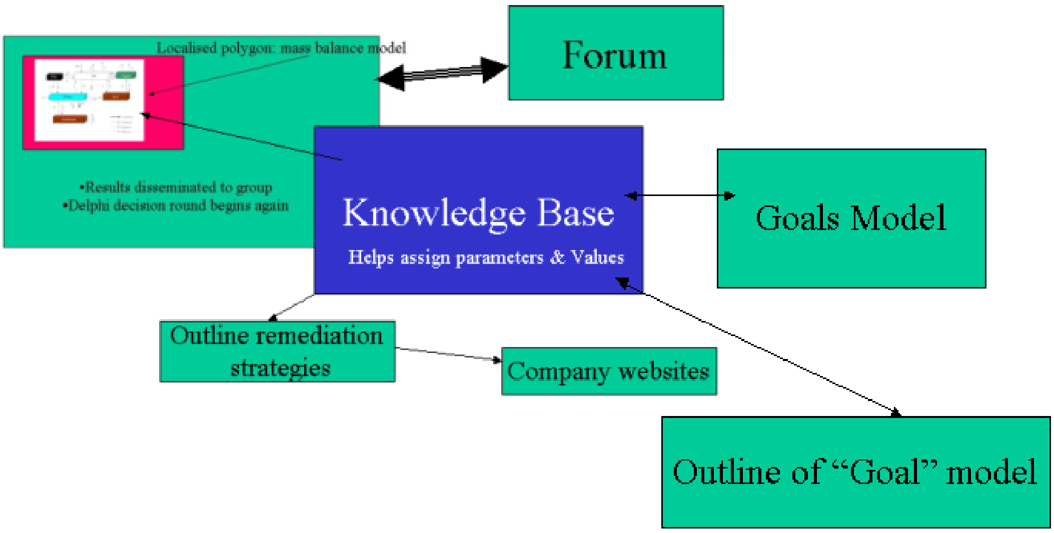

Figure 4*: Summary Of The Foundation Framework For The URBSOIL MCSDSS.*

At the heart of the system is a Web-based GIS tool. This allows all stakeholders access to the necessary technology. This means no one is excluded from the decision process. The choice of such a system must consider the lack of, potentially sensitive, data that will only be available once queries of the regional map generated by URBSOIL have reduced the land parcel choices. Technology has to be in place to allow a variety of databases, with variable GIS software formats, to be accessed and displayed.

Input of values throughout the decision process can be added via a suitable expert knowledge base, thus allowing justification and knowledge acquisition of the problem by the end-user. This knowledge base can also link to companies involved in the environmental sector, especially remediation strategies, and continuously updated to allow stakeholders continual access to emerging technologies.

An individual's assessment of a problem can be disseminated to the other stakeholders involved via an online forum. This dissemination should uncomplicated. That is by computer-generated reports presenting results together with the any assumptions and comments written by the end user during the progress of the land parcel assessment.

Generated reports should allow a series of iterative rounds, with help from an online forum to aid discussion, which will either encourage consensus or else highlight fundamental disagreements between the stakeholders.

In addition to quantifying either past or future soil quality within a land parcel, a Web-based tool for non-quantative and ill-defined environmental decision problems using the Analytical Hierarchy Process (AHP) is included. Integration of AHP with GIS is recognised as future research potential.

The many options that are available within a system such as this requires that Web development be dynamically driven, which requires the use of scripting software. Compiled server-side scripts are suitable in this regard as they have a high speed differential, compared to traditional CGI architecture, and do not require a high level of programming knowledge to achieve suitable results.

8. Acknowledgements:

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9. References

Alloway B.J. (Ed) (1997) Heavy Metals in Soils Blackie Academic and Professional, London

Ascough II, J. C. R., H. D.; Hoag, D. L.; McMaster, G. S.; Vanderberg, B. C.; Shaffer, M. J.; Weltz, M. A. & Ahjua, L. R. (2002). Multicriteria Spatial decision Support Systems: Overview, Applications, and Future Research. Retrieved 21st September 2002 from http://www.iemss.org/iemss2002/proceedings/pdf/volume%20tre/290_ascough%202.pdf .

Birke, M. & Rauch, U. (2000). "Urban Geochemistry: Investigations in the Berlin Metropolitan Area." Environmental Geochemistry and Health **22**: 233-248.

Carver, S. (1996). Potential Problems with Internet-based SDSS. Retrieved 19th September 2002 from http://www.ccg.leeds.ac.uk/mce-prob.htm.

e-transit (2002). FTA Geospatial Information Systems Survey Results. Retrieved 12th November 2002 from http://www.e-transit.org/survey.

Feick, R. D. & Hall, G. B. (1999). "Consensus Building in a Multi-Participant Spatial Decision Support System." URISA **11**(2): 17 – 23

Fokes, D. J. & Kuehster, T. E. (2001) Contributions of Pesticide Use in Urban background Concentrations of Arsenic in Denver Colorado, U.S.A. Environmental Forensics **2** 127-139

Geochoice (1996). Frequently Asked Questions about Geochoice.Retrieved 6th January, 2003 from http://www.geochoice.com/faq.html

ICLEI (1997). Urban Oasis. Retrieved 22nd May 2002 from http://www3.iclei.org/egpis/egpc-124.html

Martino (1972). Technological Forecasting for Decision Making American Elsevier Publishing Company, New York.

Miko, S. Durn, G & Prohic, E. (1999). "Evaluation of Terra Rossa Geochemical Baselines from Croatian Karst Regions. Journal of Geochemical Exploration **66**: 173-182.

NSCA (2002) NSCA Pollution Handbook National Society for Clean Air and Environmental Protection, Brighton

Thomson (2002). Web Development, University of Paisley.

Turoff, M. and S. R. Hiltz (1996). Computer Based Delphi Processes In: Adler, M & Ziglio, E (Eds.) Gazing into the Oracle: The Delphi Method and its Application to Social Policy and Public Health. London, Kingsley.

Murray Turoff, M. Hiltz, S.R. Bieber, M. & Rana, A (1998) Collaborative Discourse Structures in Computer Mediated Group Communications. Newark, New Jersey Institute of Technology. Retrieved August 2002 from *http://eies.njit.edu/~turoff/Papers/CDSCMC/CDSCMC.htm*

SEPA (2001)

UNCHS (1998). Best Practice Database Retrieved 22nd May 2002 from http://www.bestpractices.org.

Wooley, D. R. (1995). "Conferencing on the Web" in World Wide Web Unleashed Sams.net Publishing. Retrieved 24th July 2002 from http://www.thinkofit.com/webconf/forumsoft.htm

Zhang, C. & Day, M. (2002). Development of a Spatial Decision Support System on the Internet for Conservation of Stone Forest Landscape in Lunan, China Retrieved 13th September 2002 from http://www.cobblestoneconcepts.com/ucgis2summer2002/zhang/zhang.htm

HUMAN HEALTH RISK ASSESSMENT FRAMEWORK FOR CONTAMINATED SITE REVITALISATION

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European countries have different legislative and procedural approaches to contaminated site assessment and remediation or relevant legislation is under development. To evaluate contaminated sites they have incorporated different assessment procedures including risk assessment. Some of them have adopted US EPA procedures, which are especially well documented with respect to human receptors.

Within the **N**etwork **O**riented **R**isk Assessment by **I**n-situ **S**creening of **C**ontaminated Sites (NORISC) project, a site specific risk assessment (RA) framework has been designed as an additional input for a harmonised European urban contaminated site assessment strategy. The NORISC project will provide a standard guideline in the form of a decision support software system for efficient site assessment of contamination profiles in urban areas. The RA framework, as an integral module of this guideline, will be an element of strategy for the revitalisation of contaminated sites.

The risk assessment procedure refers to humans as first priority receptors in urban areas. The procedure will be adjusted to site-specific circumstances, including different land use scenarios and different types of contaminants.

Site-specific human health risk assessment procedure encompasses baseline risk assessment, including development of site data set, exposure assessment, toxicity assessment and risk characterization, as well as development of health-based preliminary remedial goals for soil and groundwater.

The RA framework has been developed for three typical urban land-use categories: residential, industrial, and recreational. Relevant to land-use category and environmental media, the following exposure pathways have been considered:

(1) Residential /industrial/recreational land uses

Soil exposure pathways:

- accidental soil ingestion
- dermal contact with soil
- soil inhalation

(2) Residential land use

Groundwater exposure pathways:

- ingestion of groundwater
- dermal contact while showering
- inhalation of volatiles from groundwater during household use.

The RA software module will be integrated with a selection of the best investigation methodology and site database. It is proposed to use the module when national limit values are exceeded.

The module will generate information on the level and spatial distribution of human health risks at a given site. Risk results will be visualised to assist decision-making and communication between different stakeholder groups.

Risk assessment results will facilitate the decision-making process to take appropriate actions to protect human health. Such actions could include site closure, remediation or revitalisation, or changing a land use pattern (e.g., from more into less sensitive). Providing health-based remedial goals for environmental media, the RA module will also be used as a basis for selecting the appropriate remediation option and for designing and conducting revitalisation of contaminated sites (Fig.1).

The RA module will provide stakeholders with a detailed scientific and technical framework to be used in revitalisation programmes. It will also allow decision-makers to design and conduct their revitalisation actions/initiatives, and to implement a well-defined methodology into an effective environmental management process.

The human health risk assessment procedure will also allow the comparison of human health risk assessment levels at different sites in different countries depending on land use scenarios. Stakeholders, including investors, will be able to use these results in a decision-making process.

Acknowledgements

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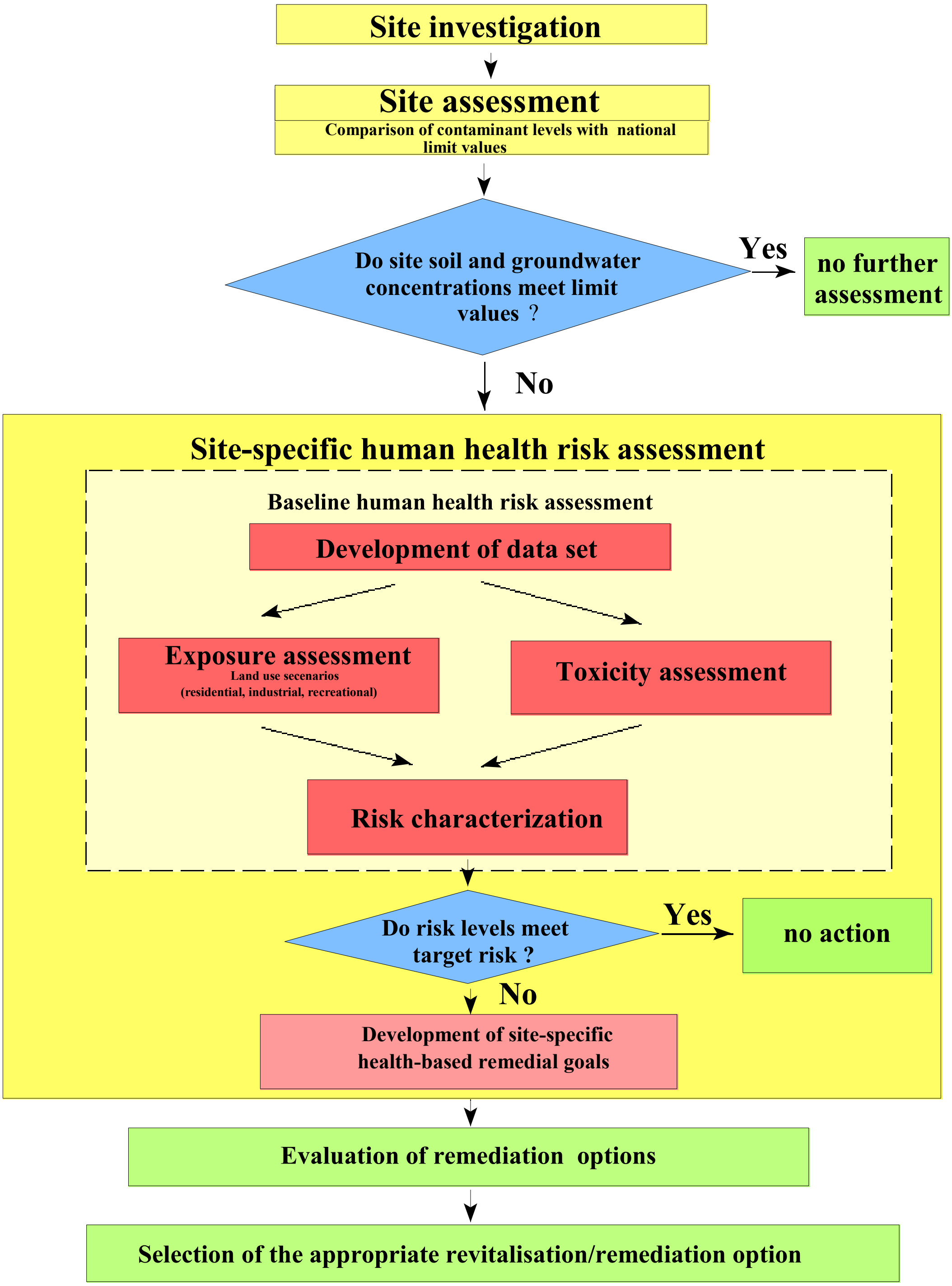

Fig.1. Risk assessment process as an element of strategy for the revitalisation/remediation of contaminated sites

A DECISION SUPPORT SYSTEM FOR THE REQUALIFICATION OF CONTAMINATED SITES: A FUZZY EXPERT APPROACH FOR COMPARING ALTERNATIVE END USES

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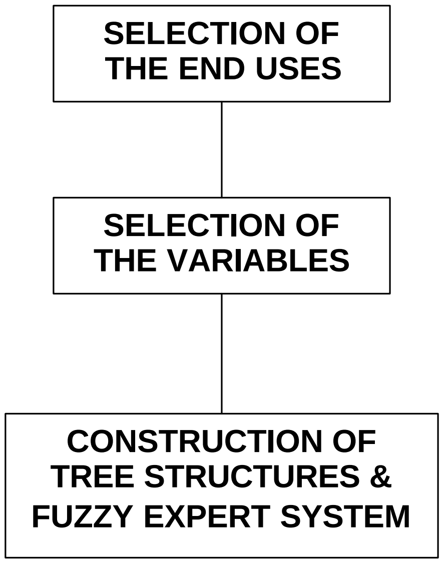
Introduction

The choice of the post-remediation use of contaminated sites is crucial for assessing the rehabilitation strategy. The latter requires socio-economic analysis to provide stakeholders with decision tools including all significant issues. It is the case of the decision support system DESYRE (Decision Support sYstem for the Requalification of contaminated sites) that implemented a software prototype for the remediation of contaminated sites. Specific contents and details of the project are reported in a contribution presented in this conference (Samiolo et al., 2002).
The specific aim of the socio-economic module included in the software is to provide the decision makers with a tool capable of comparing alternative end uses of the considered site. The end uses are the result of general socio-economic considerations and local characteristics; moreover the module design is assisted by spatial analysis' approaches. The final objective is to establish which is the "best" use for that site, on the basis of the socio-economic constraints and opportunities. The term "best" indicates that it is possible to rank the whole different end uses on the basis of a certain set of criteria. This is a typical multicriteria decision making problem, and there is not a natural order in a multidimensional space, so it is necessary to find a device to do it. A method to rank them is, fixed an end use (EU), to choose a method that defines a function from the attribute space in the real line and so obtain a total order induced by the real number one. The scientific literature is rich of several ways to approach this problem. The new researches in Artificial Intelligence propose two different types of methods: the first group is formed by Expert Systems (ES), Fuzzy Expert Systems (FES), Hierarchical methods (AHP), the second one is formed by Data-Mining methods (Neural Networks, Genetic Algorithms, etc.). The first group includes methods that are knowledge based systems: they do not use the past data and permit a real contact with the experts that may allow into the study all the experience matured in years of work in that field. The second group includes methods that are called "knowledge-discovery in data base" and are based only on data. By them the methods are able to approximate the function that describes the model. The problem is that they need a great number of data to be efficient. When the data are insufficient we have to use the first type.
We have decided to use Fuzzy Expert System for its efficiency and capacity to approximate the complicate function that describes the problem.

The model

The specific aim of the socio-economic module included in the software of the Decision Support System DESYRE is to provide the decision makers with a tool capable of comparing alternative end uses of the considered site. The final objective is to give indications about which choice can be the best for the site after remediation, on the basis of the socio-economic constraints and opportunities.
The model designed for this purpose is composed of three steps, as shown in the scheme below.



At the first step the possible alternative uses are selected; in fact, depending on the framework where the site is situated in, different uses can be hypothesized as consistent ones. The socio-economic experts collaborating to this project tried to identify all the possible end uses for a generic site, in order to make the model applicable to the general case and so exportable to different sites.
The selection has indicated six alternative end uses: residential, recreational, industrial, tourist, population services, services for business and firms. Their description is reported in the table below.

End uses	Description
1. Residential	residential area
2. Recreational	green areas, with or without facilities, to satisfy population's recreational needs
3. Industrial	industrial area with small factories and handicrafts activities
4. Tourist	tourist areas (hotels, restaurants, etc.)
5. Population services	principally the large-scale retail trade (hypermarket, mega store, etc.)
6. Services for business and firms	activities of the tertiary sector, answering the needs of firms (consulting firms, haulage contractors, retail trade)

In order to achieve the final aim of the model it is necessary to compare the socio-economic scenarios corresponding to each end use selected. To do this it is necessary to identify the variables that outline how the site answers to socio-economic constraints and opportunities linked to each alternatives (second steps of the model).
The experts identified four socio-economic dimensions as the key ones to outline the scenarios: the demand for that use at a local level, the attractivity of alternative sites for the same use, the attractivity of that site and the consistency of that use with the surrounding context (vocation index). It is then necessary to find the variables that can describe these four aspects. These variables can be different for the different end uses and also for different sites. The choice of them depends on the availability of data for the site considered, but also in this case the socio-economic experts tried to identify variables for which the values should be collected quite easily.
In the table below the variables chosen and their description are reported.

Aspect	Variable	Description	End use
Demand for the use	Number of factories	number of factories in the municipality	3, 6
	Born/death factories	ratio of born factories to death factories	6
	Population density	number of inhabitants in the municipality	2, 3, 5

	Population age 25-40	number of inhabitants in the municipality at the age of 25-40	1
	variation of the population density		1
	saturation of the hotels	level of saturation reached by the extant facilities	4
	mega stores already working	mq occupied by mega stores already working in the surrounding	5
Attractivity of alternative sites	land value	land value in €/mq in alternative sites with the same use	1, 3, 4, 5, 6
	mq alternative sites	mq available elsewhere in the surrounding for the same use	1, 3, 4, 5, 6
	mq ricreative elsewhere	mq of ricreative area present in the surrounding	2
Site attractivity	isochrones 30 min.	people that can be reached from the site in 30 minutes by car	1, 2, 3, 5, 6
	land value after remediation	land value of the site in €/mq after its remediation	1, 3, 4, 5, 6
	S distances from doors	Sum of the distances of the site from motorway, airport, harbour, rail station	3, 4, 5, 6
Context index	Local priorities	Sum of the scores assigned by experts to the local priorities, identified as the consensus of the local community towards that use, trade-union consensus coming from the increase of employments, consistency with the local planning, improvement of the quality of life, improvement of the area competitiveness, relative improvement of the environment quality, absolute improvement of the environment quality	1, 2, 3, 4, 5, 6
	Impacts on traffic	increase of the number of cars due to the end use	3, 5, 6

The comparison of the different end uses has to pass necessarily through their ranking; this can be done aggregating all the variables selected in order to obtain a final index for each end use, representing the socio-economic scenario associated to it. The logic under the aggregation can be represented through tree structures, one for each end use. At the first level of the tree there are the variables selected previously; the tree structure shows how these have to be combined to get the desired information. The final level is an aggregated variable that can represent the scenario, synthesising the socio-economic information.
This is the logic under the Fuzzy Expert System, that has been utilised to translate the model in a software. To do this we have realised six expert systems, one for each end use. Logic and methods of these expert systems are shown below.

The fuzzy model : a fuzzy expert system.

An expert system is an intelligent machine that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solutions. The knowledge of an expert system consists of facts and heuristics. The facts usually constitute a body of information that is widely shared, publicly available, and generally agreed upon by experts in the field. Heuristics concerns mostly private information and rules of good judgement that characterize expert-level decision making in the field. A fuzzy expert system is an expert system that utilizes fuzzy sets and fuzzy logic to overcome some of the problems that occur when the data provided by the user are vague or incomplete. The power of fuzzy set theory comes from the ability to describe linguistically a particular phenomenon or process, and then to represent that description with a small number of very flexible rules. In a fuzzy system, the knowledge is contained both in its rules and in fuzzy sets, which hold general description of the properties of the phenomenon under consideration. One of the major differences between a fuzzy expert system and another expert system is that the first can infer multiple conclusions. In fact it provides all possible solutions whose truth is above a certain threshold, and the user or the application program can then choose the appropriate solution depending on the particular situation. This fact adds flexibility to the system and makes it more powerful. Fuzzy expert systems use fuzzy data, fuzzy rules, and fuzzy inference, in addition to the standard ones implemented in the ordinary expert systems.

Functionally a fuzzy system can be described as a function approximator. More specifically it aims at performing an approximate implementation of an unknown mapping $j : A \subset R^n \to R^m$ where *A* is a compact of R^n . By means of variable knowledge relevant to the unknown mapping [Kosko, 1992] and [Wang, 1992] independently proved that fuzzy systems are dense in the space of continuous functions on a compact domain and therefore can approximate arbitrarily well any continuous function on a compact domain. The following are the main phases of a fuzzy system design:

1. Identification of the problem and choice of the type of fuzzy system which best suits the problem requirement. A modular system can be designed consisting of several fuzzy modules linked together. A modular approach, if applicable, may greatly simplify the design of the whole system, dramatically reducing its complexity and making it more comprehensible.
2. Definition of input and output variables, their linguistic attributes (fuzzy values) and their membership function (fuzzification of input and output).
3. Definition of the set of heuristic fuzzy rules. (IF-THEN rules).
4. Choice of the fuzzy inference method (selection of aggregation operators for precondition and conclusion).
5. Translation of the fuzzy output in a crisp value (defuzzification methods).
6. Test of the fuzzy system prototype, drawing of the goal function between input and output fuzzy variables, change of membership functions and fuzzy rules if necessary, tuning of the fuzzy system, validation of results.

In building fuzzy expert systems, the crucial steps are the fuzzification and the construction of blocks of fuzzy rules. These steps can be handled in two different ways. The first is accomplished by using information obtained through interviews to the experts of the problem. The second is accomplished by using methods of machine-learning, neural networks and genetic algorithms to learn membership functions and fuzzy rules. The two approaches are quite different. The first does not use the past history of the problem, but it relies on the experience of experts who have worked in the field for years. The second is based only on past data and project into the future the same structure of the past. The first approach seems preferable for our purpose not only as we have not a sufficient number of data, but even as our main goals are:

- constructing a general framework able to handle many cases of social-economics opportunities;
- verifying the theoretical soundness and robustness of the model through sensitivity analysis, in order to assure that actual applicability is not biased;
- showing the decision rules in a indisputable way.

We can formalize the steps in the following manner. For each linguistic variable, input x_i (*i*=1…m) and output y, we have to fix its own range of variability U_i and V . $\forall\, i$, (*i*=1…m), if n_i is the number of the linguistic attribute of the variable x_i and $\hat{n} = \max_{i \in [1,m]} n_i$, we define the sets

$A^i = \{A^i_1, A^i_2, .., A^i_{j_i}, .., A^i_{n_i}\}$, $B = \{B_1, B_2, ..., B_k, ..., B_r\}$

where $\forall\ j_i \in [1,\ n_i]$, $\forall\ n_i\ \in [1, \hat{n}]$ $A^i_{j_i}$ are the fuzzy numbers describing the linguistic attributes of the input variable x_i , and $\forall k \in [1, r]$, B_k are the fuzzy numbers describing the linguistic attributes of the output variable y.

At every elements of A^i and B a membership function is associated such that

$$m_{A^i_{j_i}}(x) : U_i \rightarrow [0,1] \qquad\qquad m_{B_k} : V \rightarrow [0,1]$$

The elements of A^i and B overlap in some "grey" zone which cannot be characterised precisely. Many phenomena in the world do not fall clearly into one crisp category or another. Experts that use abstraction as a way of simplifying the problem can contribute to identify these "grey" zones.

The choice of the slopes of the elements of A^i and B is a mathematical translation of what the experts think about the single terms.
The second step is the block-rules construction.
We define the set of L fuzzy rules, where

$L \leq \prod_1^m n_i$, $\forall\ j_i \in [1,\ n_i]$, $\forall\ n_i\ \in [1, \hat{n}]$ $\forall k \in [1, r]$

IF (x_1 is $A^1_{j_1}$) $\otimes$ (x_2 is $A^2_{j_2}$) $\otimes \ldots \otimes$ (x_m is $A^m_{j_m}$) (1)

THEN (y is B_k), (2)

The relation (1) is called "precondition" and the symbol $\otimes$ represents one of the possible aggregation operators. In practical applications, the MIN and MAX operators, or a convex combination of them, are widely used and so a "negative" or "positive" compensation will occur between them.
Instead of Min and Max, it is also possible to use other t-norms or conorms, which represent different ways of linking the "and" with the "or".
The relation (2) is called conclusion. The aggregation of precondition and conclusion can be made in several ways. The most used are the MAX and the BSUM methods. The choice depends on the type of application. The MAX has the meaning of keeping as "winner" the strongest rule, in the sense that if a rule is "firing" (activated) more than one time, the result is the maximum level of firing. In the BSUM case, all the firing degree is considered and the final result is the sum of the different level of activation (not over one). In any case, the two methods produce a fuzzy set, which has membership function $m_{agg}(y)$ .Now we have a result of the fuzzy inference system, which is a fuzzy replay. We need to return to a "crisp" value, and this step is called "defuzzification". This operation produces a "crisp" action $\bar{y}$ that adequately represents the membership function $m_{agg}(y)$. There is no unique way to perform this operation. To select the proper method, it is necessary to understand the linguistic meaning that underlies the defuzzification process. Two of these different linguistic meanings are of practical importance: the "best compromise" and the "most plausible result". A method of the first type is the Centre of Area (CoA) that produces the abscissa of the centre of gravity of the fuzzy output set

$$\bar{y} = \frac{\int_V y m_{agg}(y) dy}{\int_V m_{agg}(y) dy}$$

A method of the second type is the "Mean of Maximum" (MoM). Rather then balancing out the different inference results, this method selects the typical value of the terms that is most valid [Von Altrock, 1997].
For example we present two of the six expert systems we have built. The "industrial system" (Fig.1) and the "recreational system" (Fig.2). Of the first, we present the input drawing pictures for two variables (Fig. 3: Attractivity of alternative sites; Fig. 4: Municipal inhabitants), from which is possible to focus on the ranges, and one of the rule blocks. For all the two we present the resulting indexes we have obtained after having put as input values what the experts have estimate.

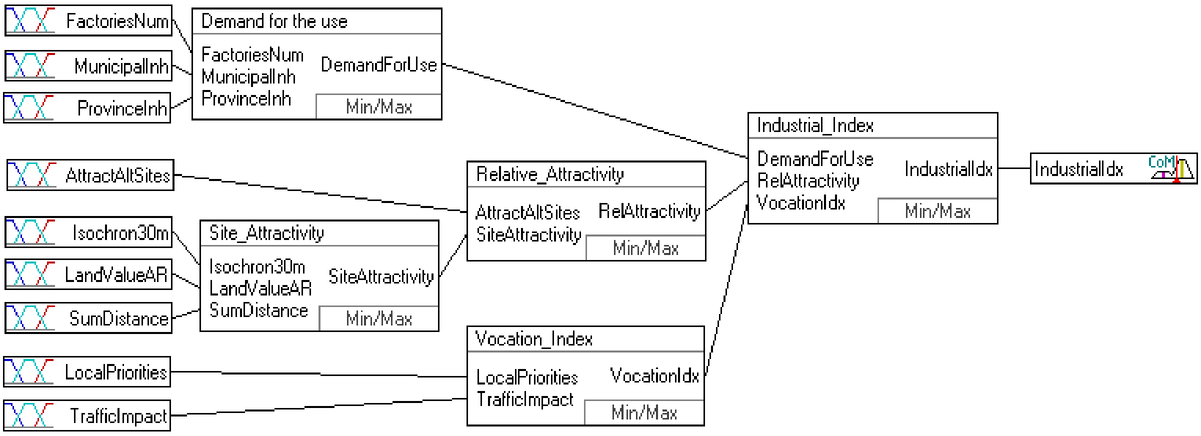


Figure 1 Tree structure for the end use "Industrial"

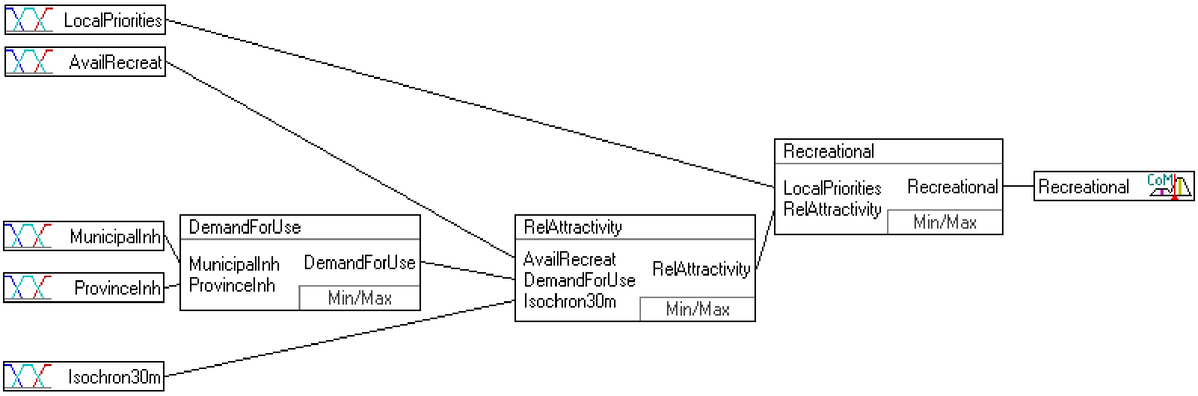


Figure 2 Tree structure for the end use "Recreational"

Abbreviations list of input, intermediate and output variables of Industrial system

AttractAltSites	Attractivity of alternative sites
FactoriesNum	Number of factories
Isochron30m	isochrones 30 min.
LandValueAR	land value
LocalPriorities	Local priorities
MunicipalInh	Population density
ProvinceInh	Population density
SumDistance	Sum of the distances from doors
TrafficImpact	Impacts on traffic
Industrial	Final index for industrial
DemandForUse	DemandForUse
RelAttractivity	Relative Attractivity
SiteAttractivity	Site Attractivity
VocationIdx	Vocation Index

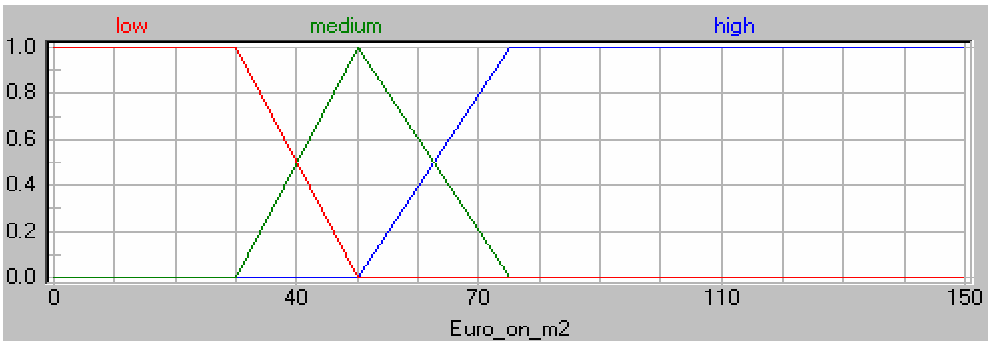


Figure 3: MBF of "AttractAltSites"

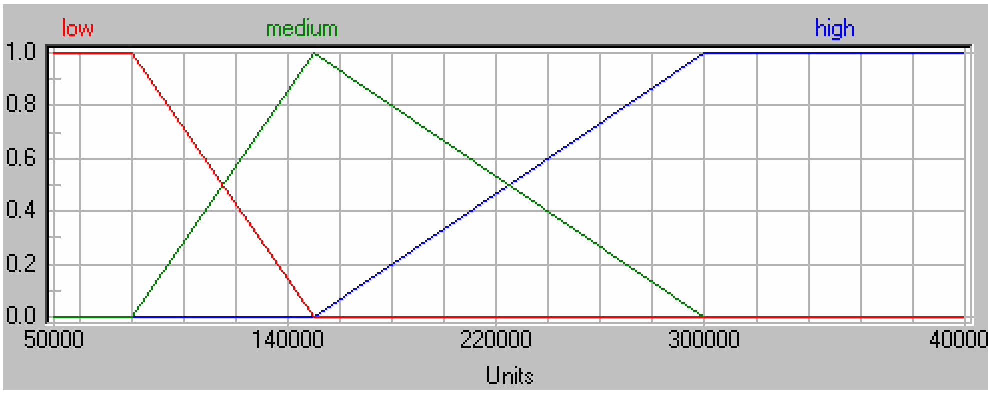


Figure 4: MBF of "MunicipalInh"

Rule Block "Demand_For_Use"

IF			THEN	
FactoriesNum	**MunicipalInh**	**ProvinceInh**	**DoS**	**DemandForUse**
low	low	low	1.00	very_low
low	low	medium	1.00	very_low
low	low	high	1.00	low
low	medium	low	1.00	very_low
low	medium	medium	1.00	low
low	medium	high	1.00	low
low	high	low	1.00	low
low	high	medium	1.00	low
low	high	high	1.00	medium
medium	low	low	1.00	low
medium	low	medium	1.00	low
medium	low	high	1.00	low
medium	medium	low	1.00	low
medium	medium	medium	1.00	low
medium	medium	high	1.00	medium
medium	high	low	1.00	medium
medium	high	medium	1.00	medium
medium	high	high	1.00	medium
high	low	low	1.00	low
high	low	medium	1.00	medium
high	low	high	1.00	medium

IF			THEN	
high	medium	low	1.00	medium
high	medium	medium	1.00	medium
high	medium	high	1.00	high
high	high	low	1.00	medium
high	high	medium	1.00	high
high	high	high	1.00	high

Table 1: Rules of the Rule Block "Demand_For_Use"

	Industrial	Recreational
Attractivity of alternative sites (€/m2)	34,47	
Impacts on traffic	1.720	
Availability of recreational activities		1.000.000
Isochrones 30 min.	25.000	200.000
Number of factories	6.000	
Number of inhabitants in the municipality	274.168	274.168
Number of inhabitants in the province	814.581	814.581
Local priorities	5	4
Σ distances from doors (Km)	10	
Land value alternative sites with the same use (€/m2)	50,00	
Site attractivity (intermediate score)	1,00	
Relative attractivity (intermediate score)	0,75	0,70
Demand for the use (intermediate score)	0,60	0,91
Vocation index (intermediate score)	1,00	
Valuation	**0,80**	**0,63**

On the basis of the results, the site can be considered more attractive for the industrial use than for the recreational one, since the final valuation index is closer to the value 1 in the first case than in the second one.

Conclusive remarks

The proposed method for assessing the attractiveness of the site for different uses, based on the fuzzy logic, can be regarded as an important tool for addressing very complex problems, characterized by the interaction between different spatial, economic and social dynamics. In this sense, the tool can be used in different territorial context to assist decision makers. Moreover, the model provides intermediate scores for the different uses; this can help to evaluate which are the strength and weakness points for each use.

It is clear that the role of experts is crucial in the decision process: they have to define the range of variability (which clearly depends on the characteristics of the territorial setting) and the block of rules. From this perspective, however, the model helps to make explicit the experts' values, and so it can help the local community to confront with them.

References

Bandermer H., Gottwald S. (1996) *Fuzzy sets, fuzzy logic fuzzy methods.* John Wiley & Sons New York.

Bruni S.-Facchinetti G.- Paba S.: (1999) "*A Fuzzy Classification for the Definition of Industrial District*" Proceedings of the 11th Italian Workshop on Neural Nets, Vietri-99. 408-413 Springer Press.
Bruni S.-Facchinetti G.-Paba S.: (1999) "*A Fuzzy Algorithm for a Defintion of Industrial District"* Advances in Fuzzy Systems and Intelligent Technologies, F. Masulli, R. Parenti, G. Pasi, Ed.s, 49-55 Shaker Publishing (NL).
Desfor G. e Keil R., Contested and Polluted Terrain, in *Local Environment*, vol. 4, n. 3, 1999.
Facchinetti G.-Ghiselli Ricci R.-Muzzioli S.: (1998) "*Note on ranking fuzzy triangular numbers*". International Journal of Intelligent Systems. Vol.13, 613-622 John Willey & Sons, Inc.
Facchinetti G.-Ghiselli Ricci R.: (1999) "*A class of ranking functions for triangular fuzzy numbers"*. Presented at NEU'99, Venezia 6-7 maggio 1999. Accepted on Economics & Complexity. 2000
Facchinetti G.-Mastroleo G.-Paba S.: (2000) *"A fuzzy approach to the geography of industrial districts"*; "Proceedings of the 2000 ACM Symposium on Applied Computing" Carrol J., Damiani E., Haddam H., Oppenheim D. Editors. ISBN: 1-58113-239-5, Vol.1 514-518.
Facchinetti G.-Bordoni S.-Mastroleo G.: (2000) "*Bank Creditworthiness using Fuzzy Systems: A Comparison with a Classical Analysis Technique*" Risk Assesment and Management in Technology, Environment and Finance. Da Ruan, Fedrizzi M. e Kacprzyk J. Editors. Springer Verlag Press. Pubblicato nella sezione Fuzzy Applications and Library del sito web http:/www.fuzzytech.com.
Facchinetti G.- Magni C.- Mastroleo M- Vignola V. " *Valuing strategic investment with a fuzzy expert system: an italian case"* on proceedings of International Fuzzy System Association Fuzzyness And Soft Computing In The New Millenium (*IFSA* 2001), July 25-28 Vancouver Canada.
Kasabov N.K. (1996) *Foundations of Neural Networks, Fuzzy Systems, and Knowledge Engineering*. MIT Press.
Meyer P.B., Williams R.H. e Yount K.R., *Contaminated Land: reclamation, redevelopment and reuse in USA and EU*, Aldershot, Gower, 1995.

PRACTICAL APPLICATION OF THE HUMAN RISK ASSESSMENT MODEL RISC-HUMAN IN RISK BASED LAND MANAGEMENT

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Introduction

Since a couple of years contaminated land management in the Netherlands is not dominated anymore by the starting point multi-functional land use. The introduction of the 'Soil Use Values' is an example of the policy change towards a 'function-oriented' approach. These Soil Use Values are meant as a remediation level. They are derived for several groups of immobile substances e.g. PAH and metals for two different land uses. But these Soil Use Values can only be used in standard situations whereas remediation according to the 'function-oriented' approach is also desired for the non-standard situations or in case of volatile compounds. For those sites should be determined to which level the contamination has to be remediated without causing any risks. Actually, this means that site specific Soil Uses Values has to be derived. But how do we derive such levels? A question that cannot easily be answered in the case it concerns complex and large contaminated sites. A suitable tool to support in finding the answer to this question might be a human risk assessment model. This paper describes the application of RISC-HUMAN, a human exposure model, in the CiBoGa case (a former industrial site). In this case the derivation of Soil Use Values was necessary to determine whether or not it is possible to redevelop the CiBoGa area without remediation.

General description CiBoGa site

CiBoGa is a contaminated site of 14 ha. The main contaminant situation at CiBoGa can be divided in three parts according to the former soil use, which included a gaswork. One part is mainly contaminated with PAH and cyanides, the other part is mainly contaminated with heavy metals and the third part with benzene, cyanide and PAH. Mineral oil was found at several spots at the site (IWACO, 1997). When the goal of the Dutch remediation strategy was still multi-functional the remediation costs were regarded to high to carry out the remediation. Due to the 'function-oriented' approach remediation might cost less and consequently more sites could be dealt with. Because of this, some land management options were introduced to re-manage the wasteland at the CiBoGa site. The proposed land use by the municipality was a combination of living, working and green area. Also a parking place was desired. CiBoGa was re-managed at time of the policy change, consequently the decision-making wasn't completely carried out according to the 'function-oriented' approach. This paper presents the application of a 'function-oriented' approach using RISC-HUMAN with examples derived from the CiBoGa case.

Strategy

The following steps should be carried out to investigate the possible developments of the three desired land uses according to a 'function-oriented' approach. Examples from the CiBoGa case are presented in Italic.

Define desired land uses

Select exposure routes that correspond with the desired land use, enter parameter values and define the time division corresponding to the land use. If necessary, several scenarios for instance in case of residential area with garden or without garden should be defined.

For the CiBoGa site three main land uses are desired; residential area, working area and public green area. All three are defined in RISC-HUMAN because of the large differences in exposure routes, parameter values and time division. If necessary the main land use can be subdivided in more specific scenarios like residential area without garden.

Define subsites according to the contamination and its level

For (large) sites with a heterogeneous contamination or soil situation it can be helpful to define subsites. This distinction will be used to compare the current contaminant situation with the demanded contaminant situation for the desired land use in a later stage of the strategy.

The CiBoGa site of 14 ha is distinguished in 21 subsites. Every subsite contains a specific contaminant situation for instance caused by differences in type of contamination, or height of concentration.

Select input data
Concentration of substances and values of soil characteristics should be selected for the human risk assessment. Which value should be selected depends on the approach of the risk assessment e.g. a worst-case approach or the use of average values. These approaches can be used on site level as well as on subsite level. Choices to use an approach depend for instance on the heterogeneity of the soil contamination as well as the goal of the risk assessment. If the goal of the assessment is to get a first indication of the possibility to develop a land use, less detailed information is required in comparison with the situation in which the goal of the assessment is to support an actual redevelopment of the site.

In RISC-HUMAN worst case concentrations are entered for every contaminant which was found at the site because only insight in the possibility of several land uses is required and not yet the reduction of concentration to achieve this. For other input data, it depended on the sensitivity of the parameter and the certainty of a parameter value which value was entered. For sensitive parameters with uncertain values, for instance open or concrete floor of a basement, a worst-case approach was used to prevent underestimation. For non-sensitive parameters as well as sensitive parameters with rather certain values, the value representing the best-case scenario was entered.

Define acceptable exposure levels to soil contamination
Soil contamination might not be the only source of human exposure to a certain substance. As a consequence humans should not be exposed via soil contamination to the maximum tolerable risk level. A Soil Use Value corresponds with an accepted exposure level thus expressed as a percentage of the Reference Dose (RfD) or the Tolerable Concentration Air (TCA), if you want to incorporate exposure to other sources in your risk assessment.

For the CiBoGa site we only want to know which land use is possible at a certain level of soil contamination. Therefore the Soil Use Value is expressed as 100 % of the exposure level of the RfD and the TCA.

Interpret results
After entering the above-mentioned data, a Soil Use Value for every measurement can be calculated. The reduction to achieve the Soil Use Value, compared with the current concentration is expressed in % of reduction (see figure 1). Comparing the Soil Use Value with the current concentrations gives information whether a site is suitable for that specific land use or not.

For CiBoGa was chosen to enter worst-case concentrations for every substance in RISC-HUMAN. The calculated Soil Use Values were compared with the measured concentrations at the subsites. Depending on the understanding of the contaminant situation of the subsites and the goal of the investigation, worst case or average concentrations were used as representative concentration of the sub site. The comparison of the concentrations is executed for every desired land use starting with the most sensitive one. When a Soil Use Value is not exceeded it means that the desired land use and all less sensitive land uses can be realized at the sub site. However, if a concentration exceeds the Soil Use Value that specific land use cannot be realized without remediation measures. The extend of exceeding was taken into account. For subsites in which the concentrations hardly exceeded the Soil Use Values, is investigated which parameter changes can influence positively the development of a desired land use, expressed by increase of Soil Use Value. Adding a scenario in RISC-HUMAN with a changed parameter value provides understanding of land use possibilities for which certain building demands or user restriction counts (see figure 2). For instance buildings with thick concrete floors instead of open floors.

I use values RISC Human version 3.0

Scenario : Residential area

Allowable exposure due to soil contamination (% of RfD or TCA): 100 %

Measurement	Substance	Current concentration [mg/kg]	Soil use value [mg/kg]	Reduction [%]
Arsenic - max	arsenic	2.70E+01	2.70E+01	0
Nickel - max	nickel	5.60E+01	5.60E+01	0
Cadmium - max	cadmium	4.80E+00	4.80E+00	0
Lead - max	lead	8.00E+03	1.46E+03	82
Naphtalene max	naphtalene	2.90E+00	2.90E+00	0
Phenanthrene	phenanthrene	1.20E+01	1.20E+01	0
Anthracene - ma	anthracene	5.00E+00	5.00E+00	0

Figure 1: Example of the calculated Soil Use Values in RISC-HUMAN

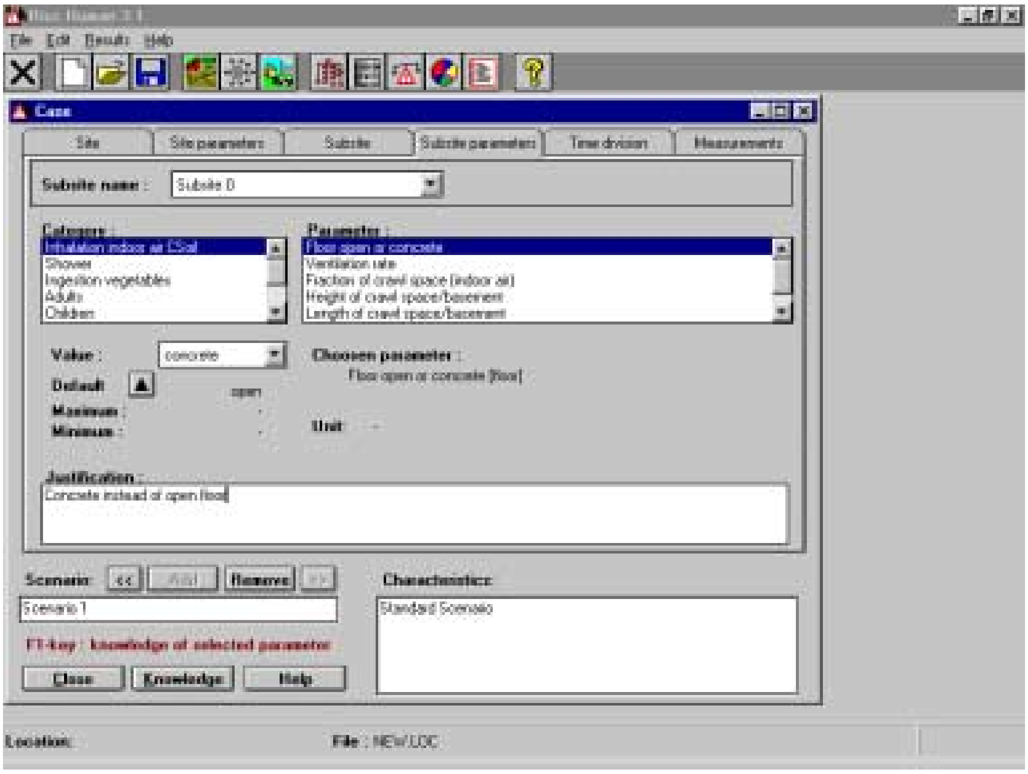

Figure 2: Extra scenario with different input data in RISC-HUMAN

Decision making
Making decisions about risks should always include the judgment of input data. The better the insight in possible changes of these input data and it's influence, the better a decision can be made and founded.

Several decisions can be made on the results. Those decisions can be:
- all or none of the desired land uses are possible;
- parts of the site has to be remediated;
- less sensitive land uses or land uses with restrictions have to or can be developed on the site;
- more investigation is required to make a decision about land-use possibilities.

For CiBoGa counts that not all of the desired land uses can be realized. For those places an underground parking place can be realized, as a consequence soil should be removed and risks will be reduced.

Conclusion
The application of RISC-HUMAN in case of CiBoGa shows the possibilities of a human risk assessment model to support the decisions made in the approach of 'function-oriented' remediation in the Netherlands.

References
IWACO, 1997
IWACO (1997) *Aanvullend Saneringsonderzoek en Saneringsplan CiBoGa-terrein Groningen,* Groningen.

CABERNET: ENHANCING EUROPEAN OPPORTUNITIES FOR SUSTAINABLE BROWNFIELD REGENERATION

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SUMMARY

1 This paper describes CABERNET – a multidisciplinary expert Network funded under the 5th Framework programme of the European Commission (Key Action 4: City of Tomorrow and Cultural Heritage - http://www.cordis.lu/eesd/ka4/home.html) aimed at enhancing the sustainable development of brownfield sites.

2 The paper provides information on:

- Aims and objectives of the Network;
- Context of CABERNET's work;
- The Members of the Network;
- Activities of the Network;
- Outputs; and
- Sources of further information about the project.

3 Linked to this paper, an additional paper being presented at the Consoil 2003 conference (CABERNET Special Session: SpS 14) discusses some of the key scientific, practical and political issues currently identified by CABERNET for debate and further exploration during the course of the project.

AIMS AND OBJECTIVES OF THE PROJECT

4 CABERNET's vision is the enhanced rehabilitation of brownfield sites within the context of sustainable development of European cities, by the provision of an intellectual framework for coordinated research and development of tools.

5 It has as its key objectives:

- Better awareness and shared understanding of brownfield issues across Stakeholder Groups
- A conceptual model for brownfield issues
- Coordinated research activities across different sectors and countries
- Identification of best practice approaches and other tools

6 CABERNET focusses on bringing together ideas and information, as well as stimulating the development of new initiatives.

CONTEXT OF CABERNET'S WORK

7 Brownfields result from changing patterns of industry and development in many regions. CABERNET took as its starting point the definition of brownfield developed during the CLARINET project (Brownfields and Redevelopment of Urban Areas: A CLARINET report http://www.clarinet.at/library/brownfields.pdf). Brownfield sites have been described by the CLARINET Working Group 1 as "sites which:

- have been affected by former uses of the site or surrounding land;
- are derelict or underused;
- have real or perceived contamination problems;
- are mainly in fully or partly developed urban areas; and
- require intervention to bring them back to beneficial use."

8 Recent developments in the USA suggest that the association of real or perceived contamination with the term brownfield is gaining wide international acceptance. Although much previously-developed land requires intervention to bring it back to beneficial use, it may not be affected by contamination issues.

9 The loss of industry, the resulting unemployment and the reluctance of new investors to take on the technical problems and potential costs associated with brownfield sites all affect the economic prosperity of the region, the quality of the environment and the viability of local communities. Across Europe, concerns about the shape of urban living, and in particular the problems relating to urban sprawl, mean that reuse of brownfield sites is increasingly seen as an important component of sustainable cities. In addition, increasing concerns relating to the loss of agricultural soil to new developments and the potential long term health and environmental impacts of contamination (often associated with former industrial sites) are focussing attention on the need for appropriate remediation and reuse of land as part of a risk-based land management strategy.

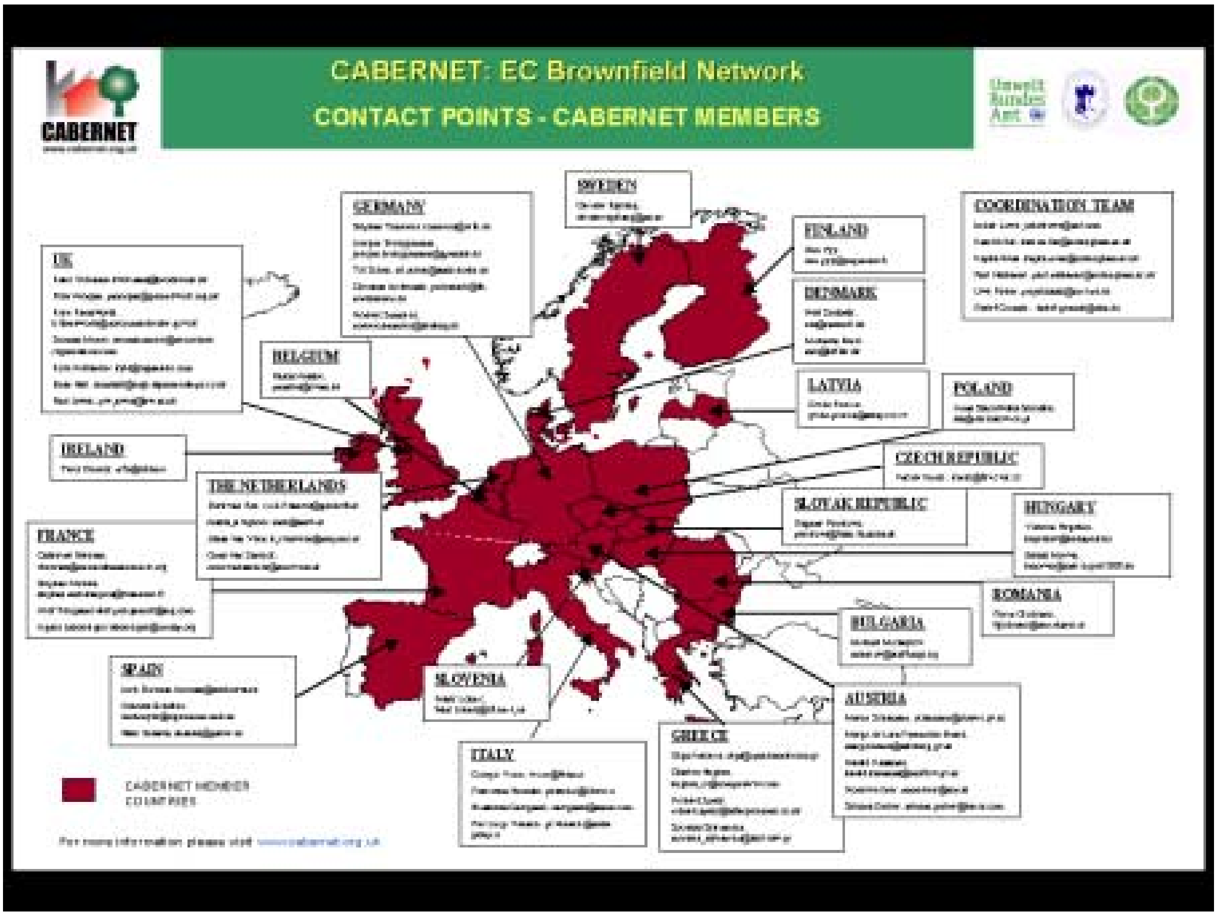
10 CABERNET provides a forum for European wide interaction of different Stakeholder Groups, creating the opportunity to find and exchange practical and sustainable solutions to the problems of urban brownfields. It looks at both strategic and site specific levels of the complex integration of market forces, environmental pressures, and social and cultural heritage aspects which characterise brownfields.

THE MEMBERS OF THE NETWORK

11 CABERNET is coordinated by the University of Nottingham, UK. It is supported by the Umweltbundesamt, Germany (UBA) and developed from the Working Group on brownfields set up by UBA as part of the CLARINET project. Projektgruppe Stadt+Entwicklung act as a special advisor in the Coordination Team.

12 The Network consists of 49 Members originating from 21 countries across Europe – shown in the map below.

Figure 1: CABERNET Members (available on www.cabernet.org)



13 CABERNET has a distinct multidisciplinary flavour, consisting of members from a wide range of professional backgrounds including environmental science, engineering, spatial and urban planning, law, sociology, and political administration. The Members are drawn from across the European Community and accession countries and represent a range of different types of organisations, from industry and research organisations, to policy makers and municipal authorities, through to representatives of local community organisations.

14 In addition to the Members of the Network, who receive travel and subsistence support from the EC for their participation in CABERNET activities, a number of Associate Members support the Network and are involved in meetings. Where possible, CABERNET also includes other invited experts at its meetings, particularly those from countries or types of organisation not directly involved in the project.

15 CABERNET Members represent a range of stakeholders in the brownfield redevelopment process. The diagram below shows the "stakeholder" categories which broadly underpin the CABERNET project, and their main position in relation to the brownfield redevelopment process.

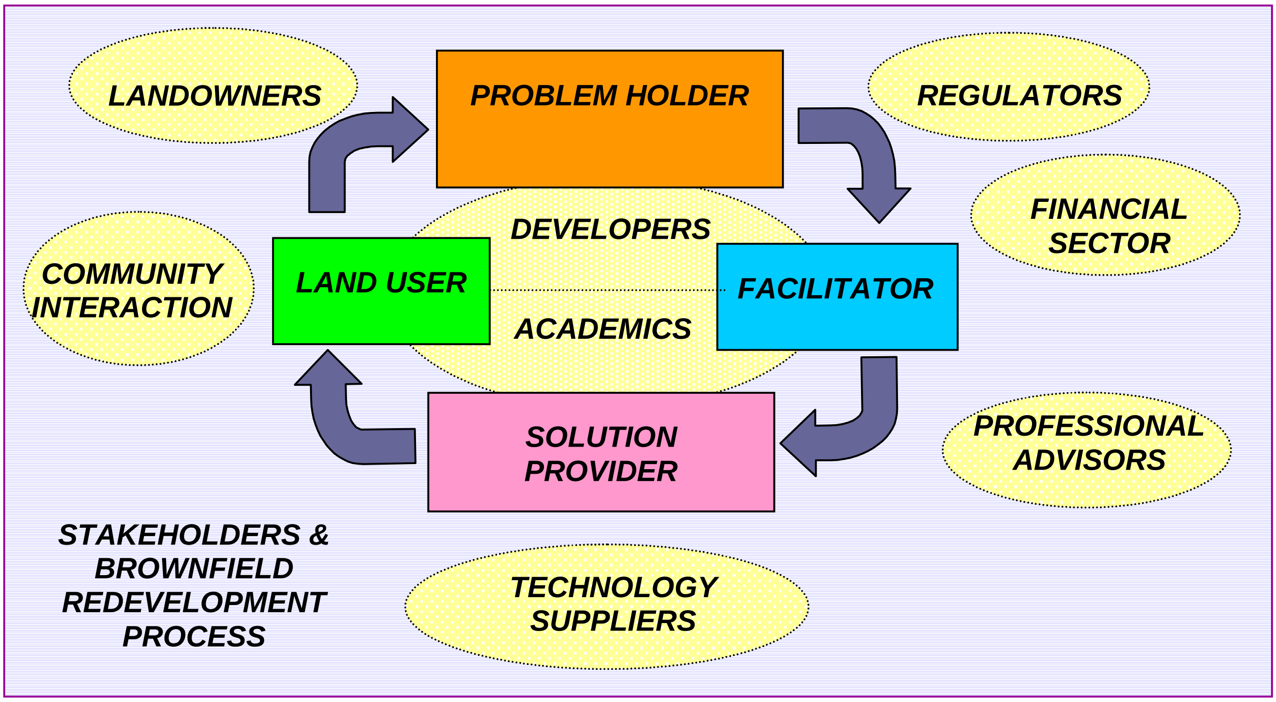


Figure 2: CABERNET Stakeholder Categories

ACTIVITIES OF THE NETWORK

16 The main activities of the Network have been built around a series of meetings structured to support the development of specific CABERNET outputs, but aimed at maximising the opportunities for interaction between different Stakeholder Groups or for exchange between different organisations and countries.

17 CABERNET's work programme is divided into 3 main phases – running in total from January 2002 to December 2004

- Stakeholder Group interaction (year 1)
- Work on specific components of sustainable regeneration of brownfields (year 2 and part of year 3)
- Integration of final outputs (end of year 3)

18 In the first year the project has been steered by a Coordination Team set up by the University of Nottingham and by representatives of the Stakeholder Groups who have acted as "Team Leaders" to manage meetings and produce specific outputs from their groups.

The individuals who have supported the project in this way in year 1 are shown below:

Coordination Team	Stakeholder Group Team Leaders
Judith Lowe, Project Director, UK	Nora Meixner, Austria
Kate Millar, Project Manager, UK	Neel Stroebaek, Ramboll, Denmark
Kapka Nilan, Project Assistant, UK	Eddy Wille/Pascal Maebe, OVAM, Belgium
Paul Nathanail, Principal Investigator, UK	Christian Juckenack, Fachhochschule Nordhausen, Germany
	Dagmar Petrikova, Slovak University of Technology, Slovak Republic
Detlef Grimski, Project Advisor, Germany	Christer Egelstig, JM AB , Sweden
Uwe Ferber, Project Advisor, Germany	Peter Morgan, Groundwork, UK
	Seumas Munro, SecondSite Property, UK

Stakeholder Group interaction in year 1

19 The Network started with a series of paired Stakeholder Group meetings which took place in different locations across Europe. The pairings reflected potential synergies and tensions in the development process as follows:

TABLE 1: PAIRED STAKEHOLDER MEETINGS AND VENUES		
Location	**Paired Stakeholder Groups (SGs)**	
Vienna, Austria	Financiers	Technology Providers
Mechelen, Belgium	Landowners	Regulators
Birmingham, UK	Community Groups	Developers
Bratislava, Slovak Republic	Academics	Professional Advisors

20 During the meetings the Stakeholder Groups explored their own role in the process, and the role of others, and exchanged views on this with the other Stakeholder Groups. They also worked on specific outputs aimed at facilitating the understanding of brownfield issues across Europe. The groups also used site visits at the meeting locations to learn together about specific brownfield approaches in different places.

21 At the end of year 1, all eight Stakeholder Groups met concurrently in Athens before a Network Plenum meeting. They used the opportunity to mix in new pairings and focus on the specific outputs (discussed below).

22 Finally, the groups came together in a Plenum day, which also included invited local speakers and other international experts on European and US brownfield policy and programmes. Speakers from the Network presented the draft outputs from the work of the Stakeholder Groups. Members of the Network and other attendees discussed some of the broader intellectual and practical issues relating to the analysis of brownfields problems and the development of solutions.

Work on specific components in sustainable regeneration of brownfields in Year 2

23 Building on the discussions in the Stakeholder Groups during the Plenum meeting, the Members of the Network identified a number of potential topics for the work programme for the second phase of the project. These have been collated under 6 broad themes identified at the outset of the project as representing key aspects of sustainable regeneration of brownfields at a European level:

- Economic issues
- Environmental issues
- Social issues
- Policy and regulation
- Skills
- Citizen participation

24 During 2003 Working Groups will meet to discuss the topics, consider how CABERNET can assist in advancing understanding and developing multidisciplinary and multi-stakeholder solutions relating to the issues raised, and initiate a work programme to support appropriate outputs from the Network.

Other activities of the Network

25 In addition to its activities focused around meetings within the Network, CABERNET is involved in a wide range of interactions with other Networks, projects and initiatives. CABERNET aims both to facilitate linkages between these other activities relevant to the regeneration of brownfields and to provide expert input from a multi-stakeholder and European perspective on brownfield regeneration.

26 Strong links and cross participation have been established with other Networks relevant to particular aspects of brownfield regeneration. These include links with: BERI (Brownfields Europe Regeneration Initiative involving 15 Member Cities and Local Partners including academics, private sector organisations, regeneration agencies, and community groups); Regentif, (a European Network, funded under the EC Innovation and SMR programme, for enhancing innovation in regenerating old industrial facilities); NICOLE (Network for Industrially Contaminated Land in Europe. NICOLE is industry-led network which provides a forum for the dissemination and exchange of scientific and technical knowledge relating to contaminated land management in Europe); the Common Forum on Contaminated Land (consisting of representatives from policy advisors and regulators from member states); and the Ad Hoc International Working Group on Contaminated Land (a worldwide Network of policy advisors, regulators and government agencies).

27 CABERNET also links to other projects funded by the EC relating to brownfield regeneration such as RESCUE (Regeneration of European Sites in Cities and Urban Environments - http://www.rescue-europe.com), NORISC (Network Oriented Risk Assessment Screening of Contaminated sites - http://www.norisc.com/). The work of these projects complements that of the Network, as they are funded to produce specific outputs relating to particular research topics. Members of CABERNET are involved in a number of these projects, and CABERNET provides a forum to assist in reviewing and disseminating project outputs. CABERNET has also participated or provided input to other EC projects such as IMAGE- TRAIN (Innovative Management of Groundwater Resources in Europe Training and RTD Co-ordination Project - http://www.image-train.net/), EUGRIS (European Groundwater and Contaminated Land Remediation Information System), which are projects largely relevant to the contamination aspects of brownfields.

28 At a national level, CABERNET has provided expert input to two major reviews of policy and practice in the funding of brownfield regeneration – one by the Office of the Deputy Prime Minister (ODPM) in England and the other for Openbare Afvalstoffenmaatschappij voor het Vlaamse Gewest (OVAM) in Flanders. Members have also participated in a number of national and international conferences on brownfields.

OUTPUTS

29 In its first year, CABERNET worked on the development of outputs which collated information about brownfield issues and helped to raise awareness of problems. Finalisation and updating of this information will continue during the remainder of the project, covering:

- The scale and nature of brownfields in Europe
- Policy and regulatory practices
- Financial issues
- Skills
- Tools available
- Research and development
- Case studies
- Contact points for relevant organisations

30 CABERNET also intends to develop a conceptual model to assist in describing and analysing aspects of brownfield regeneration, as well as a route map for the process. It is also trying to stimulate identification and discussion on the drivers and pressures which influence the way in which brownfield regeneration process takes place and its impact.

31 During the second and third phase CABERNET will explore the development of a range of different outputs to assist in sustainable regeneration of brownfields.

32 These and other specific outputs will form a family of CABERNET data and reports, information sheets, briefing papers and links to other sources, all accessible on line through the web site.

SOURCES OF FURTHER INFORMATION ABOUT CABERNET

33 Further information about the Network and a number of CABERNET outputs, including reports, papers, on-line databases, Information Sheets, and other valuable brownfield-related resources, are available on the CABERNET web site at *www.cabernet.org.uk*.

CONCLUSIONS

34 CABERNET intends to inform thinking by creating an innovative intellectual and practical framework, bringing together the key aspects of the environment, economy and society associated with sustainable regeneration of brownfields. CABERNET hopes that, as a result of its work, a wide range of stakeholders involved in the process (such as policy makers, regional and municipal authorities, industry and small businesses, as well as professionals and scientists) will have a greater awareness and understanding of the problem, as well as access to an improved information base and solutions which will facilitate the sustainable use of brownfields.

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The authors would also like to acknowledge the enthusiasm and input from the Members of the Network and others who have supported and participated in the work programme, particularly the Associate Members, the hosts of meetings and the expert speakers. Full details of all those involved are provided on the CABERNET web site.

HEALTH RISK ASSESSMENT PROCESS AS A TOOL FOR DECISION-SUPPORT SYSTEM IN GROUNDWATER MANAGEMENT

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Management of groundwater quality is based on the principle that groundwater resources should be used as the source of drinking water. It means that health issues serve as the basis for groundwater quality assessment. In view of these assumptions, policy issues are identified, assessment and management schemes are shaped, assessment criteria and methods are defined. It should be stressed that groundwater assessment criteria are linked along a logical structure of the cause - effect chain, starting from the human health effect as the basis. There is a general scheme for risk assessment of groundwater contamination which comprises the following criteria:

- criteria of contaminant migration between environmental compartments (mass flux of contaminant parameter),
- criteria of groundwater quality or drinking water quality (contaminant concentration),
- health risk posed to populations exposed to contaminated groundwater.

The criteria are complementary to each other, with the basic reference drawn out from health risk criteria.
The groundwater quality management systems in Europe are based more on generic solutions than site - specific tools. In national legal systems in Europe those criteria are incorporated into management systems in a generic way through quality requirements: drinking water standards or groundwater quality standards. Generic approach is applied in the legal systems of most European countries e.g. Italy (DM, 1999), Germany (FSPA, 1998) and Austria (ACCS, 1989; GSWV, 1991). This approach employs a standardised set of assessment criteria; usually a double quality standard scheme is set up with trigger and intervention values – Germany (FSPA, 1998), Austria (GSWV,1991; ONORM 2088-1, 1997). Trigger values are used for screening purposes of the environmental quality while intervention values are the starting point for remediation action. At the same time intervention values of particular parameters serve as reference for setting remediation goals for contaminated groundwater. The basic scenario of human activity, which is taken upon in a generic approach, is the drinking water scenario. In this scenario groundwater quality is assessed as directly intended for human consumption.

Health risk assessment in the context of legal requirements can be viewed as a complementary tool useful in site-specific management conditions. Performing health risk assessment ensures a more flexible groundwater quality management, especially in the following cases:
- complex mixture of contamination for which there is a suspicion that generic standards are not sufficient in protecting groundwater quality and human health at the same time;
- different scenarios of current and future groundwater use (fit for use approach);
- possible significant population exposure to groundwater contamination;
- extensive historical pollution;
- exemptions where it is difficult to achieve legally required standards due to technical, economical and social reasons.

For those cases application of health risk assessment, taking into account specific groundwater use scenarios could provide a basis for a more adequate decision addressing a given site.
Health risk assessment (HRA) can be viewed as a process of evaluating current and potential future adverse effects on humans in specific contexts of a given site. Health risk assessment methodology can be used in a

number of purposes in the management cycle comprising investigation, assessment and remediation of the contaminated site. The role of HRA process within groundwater quality management system can be as follows:
-provide information on the level of health risks (Baseline risk assessment),
-set preliminary remedial goals (e.g. Risk-Based Concentrations),
-assess remediation effects.

Theoretically, health risk assessment application can be oriented along precautionary principle and the fit for use principle. Precautionary application of HRA provides a better system of assessment in terms of the contamination scope and health effects evaluation in comparison to quality standards, which usually give a limited scope of the assessed problem. On the other hand, application of HRA in the context of the fit for use principle allows for a more liberal approach in the management of contaminated land, also in the case of contaminated groundwater. Furthermore, HRA results can be used in a more flexible way in the multi-criteria decision model, in which other criteria e.g. economical and social are taken into consideration at the same time. Decisions made with the use of this model are more realistic in the perspective of sustainable development at a given site.

Health risk assessment can be used in evaluating historical data at sites with extensive pollution, and complex contamination resulting from historical process of socio-economical development – usually abandoned post-industrial sites. For such cases precautionary approach (drinking water and other exposure scenarios) within health risk assessment procedure should be applied. HRA can be used in those cases as a tool for site characterisation, screening, definition of the management problem as well as planning further investigations.

Use of HRA in the context of precautionary approach for contaminated sites with complex, mixed contamination of soil and groundwater is important at the stage of detailed assessment. Then, suspection concerning potential health effects should be clarified independently to generic assessment. Appropriate assessment procedure should take into account the full spectrum of contaminants, and potential synergistic health effects of contaminants in drinking water scenario. In that way health risk assessment is used in a conservative way. From management point of view, conditions and criteria of HRA application in complex cases are as follows:
1 mixture of different chemical groups of contaminants (pesticides, PAH, chlorinated hydrocarbons, heavy metals, etc),
2 highly toxic contaminants within the same group,
3 contaminants - for which there are no legally bound strict recommendations.

Other site-specific situation for assessment arises when there is a possibility that the scale and quality of site contamination is changed due to implementation of a remediation technology. For precautionary reasons the possibility of changes in the environment should be taken into account. The following possibilities should be screened:
1. possibility of toxic contaminants generation in the environment as a result of remediation technology implementation,
2. quantity changes of contaminant concentration as the result of remediation process - possible temporary rise in the toxicity.

In many European countries e.g.: France (Sauvalle, Darmendrail, 1999), Germany (Bieber et all, 1999), Austria (Muller, Schaman, 1999) and Netherlands (Denneman, 1999) those situations are covered, to some extent by systemic solutions based mostly on generic approach but including also HRA in tiered procedures. Health risk assessment is included in the final part focused on detailed assessment of the contaminated site.

It should be stressed that the proposed HRA application within management schemes present HRA rather as a soft instrument of management, complementary to the assessment systems required by country legal systems. HRA is easy to use, especially in the cases were the liabilities for contaminated sites are posed on administration as the responsible body. Site –specific health risk assessment can give a better management perspective, verifying the results of generic assessment in the context of local environmental conditions and in the context of updated knowledge.

In the fit for use approach health risk assessment is used as a flexible tool of setting remediation goals in accord with economic and social reasons. In that case HRA is used as an integrated tool of multi-criteria decision-making model. Usage of the health risk assessment in cost-efficiency analysis depends on groundwater policy requirements. In such a model, decisions concerning groundwater remediation consider criteria other than environmental quality including economic and social aspects. Those decisions are made at the point of setting remediation goals and choosing remediation technology options.

In the situation when different quality categories of groundwater can be legally established in the contaminated area, non-standard exposure pathways - scenarios can be taken into account in the decision - making process. As a result decisions on the usage of groundwater not qualified for drinking purposes might be taken (agricultural use, industrial use or temporal drinking water use) into account according to a given policy settings. This strategy is potentially useful in complex contamination cases at those sites where the dimension of the problem require more complex management schemes.

Health assessment procedure

Effective application of HRA methodology in groundwater quality management requires adjustments of the procedures to current country/regional legal requirements. When incorporating HRA into these procedures, both difficulties and benefits of the application should be taken into consideration (Table 1).

Table 1 Health risk assessment in groundwater quality management: difficulties and benefits (Gzyl et al., 2001)

Difficulties	Benefits
- administration must understand health risk issues	- health risk level depicted in a clear and comprehensive way
- administration procedures are more complex	- the results are better grounded and verified
- a number of decision options may be generated	- basis for flexible decision-making provided
- expert judgement is necessary	- up-to-date knowledge utilised
- more effort of risk communication is needed	- exposed population is better informed
- validated information on exposure factors required	- uncertainties are tackled in a proper way

A number of aspects are important in the adjustment of the procedure to country/regional legal settings:

- role of quality standards in the assessment and management (risk criterion is secondary, complementary or primary in the assessment),
- use of risk criteria in the procedures (management and assessment tools),
- legal settings for health risk assessment - (in most countries it is explicitly determined, in some it is not clear),
- who is allowed to perform risk assessment,
- methodological requirements for risk assessment defined by law.

Legal systems in Europe usually do not define strict procedures of health risk assessment. These procedures are connected with environmental quality monitoring and evaluation issues. It is rather a matter of practice, and state of the art. For that purpose, appropriate guidelines and appropriate population characteristics are provided.

The fact that HRA methodology can be easily modified with the use of deterministic and probabilistic approaches, accordingly to the chosen scenarios and uncertainties of the assessment is a very important feature. In that way a variety of problems can be covered. In conventional “point” approach to risk assessment, single values of variables such as exposure parameters are used (deterministic approach). In the probabilistic approach based on upon the Monte Carlo techniques, all variables and parameters used in risk assessment can be treated as distributions throughout analysis. Study on the possibilities of HRA implementation indicated that HRA should be incorporated within a tiered procedure as a final step after groundwater quality screening and preliminary evaluation (Figure 1). This tiered procedure is complementary to legal provisions concerning risk assessment in European countries.

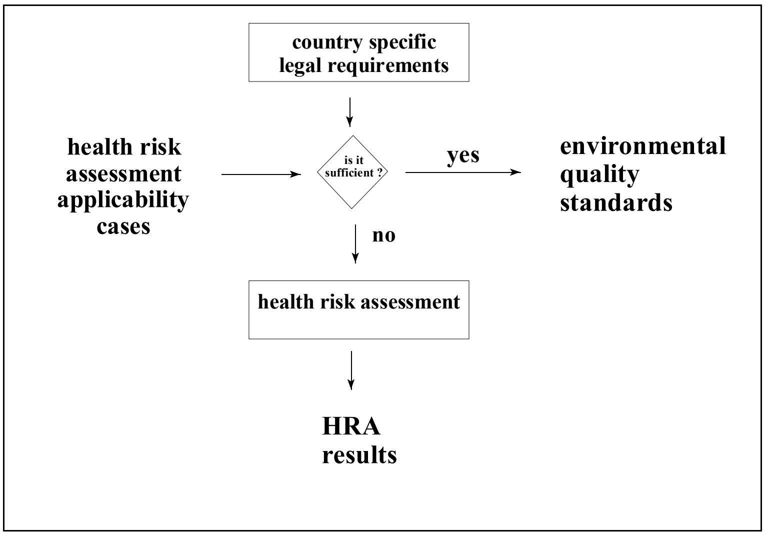

Figure 1 Health risk assessment in groundwater quality management

The methodology of health risk assessment was employed in the 5 FP UE project: Integration Concept for groundwater Remediation (INCORE) and put to practice in project test sites: in Milan, Stuttgart and Linz. HRA procedure within INCORE was developed as flexible tool which can be used in different management settings (Figure 2).

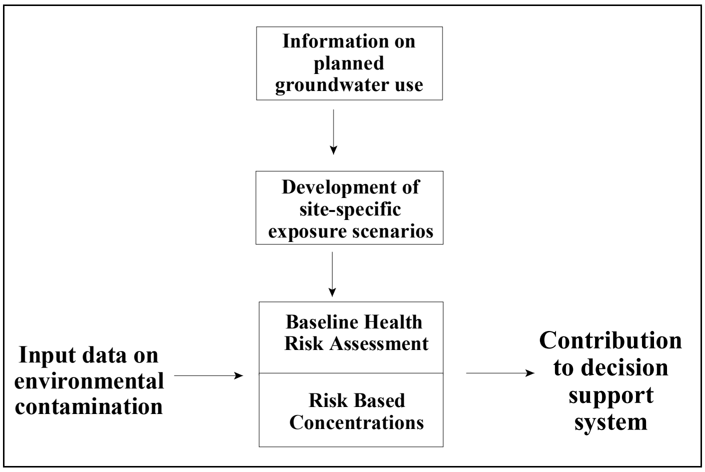

Figure 2 Health risk assessment procedure in the INCORE project

Health risk assessment usually requires involvement of health risk assessment experts to carry out the assessment. In some steps of the procedure the authorities can perform the assessment based on commercially available programmes. There are different requirements concerning responsibilities for carrying out the assessment procedures. They are as follows:

- simplified risk assessment - the assessment can be performed using commercial tools. Especially for screening purposes conservatively adjusted assessment can be performed by administrators.
- detailed risk assessment - expertise is required, validation of results also requires expert judgement.

Conclusions

In the conservative approach the use of health risk assessment is limited by its legal status; criteria more stringent than environmental quality standards are more difficult to apply in practice when the liabilities of other parties are involved. On the other hand a liberal approach is difficult to defend in the context of social risk perception. Implementation of health risk assessment in a wide scale requires better understanding of the health risk essence among the actors, involved in the decision-making process. Harmonisation of risk procedures and validation of risk assessment knowledge basis seem to be the best way for an effective application of health risk assessment. Application rules should be defined in a clear way. Such a procedure recognised on the European level could serve as a starting point for an effective use of health risk assessment procedure, in the management of contaminated sites with groundwater problems.

Acknowledgements:
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References:

ACCS/Austrian cleanup act (1989): The Act for the Cleanup of Contaminated Sites, Federal Legal Gazette No. 299/1989.

BBodSchV/German soil protection ordinance (1999): Federal Soil Protection and Contaminated Sites Ordinance, 12 July 1999.

Bieber A., Franzius V. Freier K. (1999): Germany, in Ferguson C.C. and Kasamas H. (ed.) Risk Assessment for Contaminated Sites in Europe. Volume 2. Policy Frameworks LQM Press, Nottingham, p. 61-76; with update 1/2000, Andreas Bieber/German Ministry for the Environment, Caracas.

DM/Italian reclamation law (1999): Polluted sites reclamation, DM 25 October 1999, Law n.471, 16.12.1999.

Denneman C. (1999): Netherlands, in Ferguson C.C. and Kasamas H. (ed.) Risk Assessment for Contaminated Sites in Europe. Volume 2. Policy Frameworks LQM Press, Nottingham, p.107-121.

FSPA/German soil act (1998): Federal Soil Protection Act of 17 March 1998, Federal Law Gazette I p. 502.

GSWV/Austrian drinking water ordinance, (1998): Verordnung hber die Qualit@t von Wasser fhr den menschlichen Gebrauch (Ordinanace on the Quality of Drinking Water) BGBI No. 235/1998.

Gzyl J., E. Wcisło, M. Biesiada, J. Krupanek and G. Gzyl, 2001: Human Health Risk Assessment in the Management of Groundwater Resources. Proceedings of the 1st IMAGE TRAIN Cluster Meeting, Karlsruhe, 7-9 November, 2001(166-171). Available on the IMAGE TRAIN website:http://www.image-train.net/products/proceedings_first/chapter_29.pdf

Mhller D., Schaman M. (1999): Austria, in Ferguson C.C. and Kasamas H. (ed.) Risk Assessment for Contaminated Sites in Europe. Volume 2. Policy Frameworks LQM Press, Nottingham, p. 6-10.

ONORM S 2088-1: Altlasten - Gefardungsabschtzung fur das Schutzgut Grundwasser, Vienna, 1 October 1997.

Sauvalle B., Darmendrail D. (1999): France, in Ferguson C.C. and Kasamas H. (ed.) Risk Assessment for Contaminated Sites in Europe. Volume 2. Policy Frameworks LQM Press, Nottingham with update 1/2000 Emmanuel Normant/French Environment Ministry, Caracas, p.49-60.

AUTOMATIC DELIMITATION OF HYDROLOGICAL UNITS AS A BASE FOR HOT-SPOTS CLUSTERING IN GIS ORIENTED MANAGEMENT SYSTEMS

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The poster presents the methodology of automatic delimitation of hydrological units. This method was developed in the Institute for Ecology of Industrial Areas in Katowice for the needs of "WELCOME" - project realized within 5 UE Frame Program. One of possible approaches to the contaminated site management on large areas called megasites is connected with necessity of site classification and grouping. Information about hydrological and hydrogeological properties of different sites is a base for site classification. The first step in this approach is connected with delimitation of hydrological units i.e. spatial units with similar hydrological properties. This units are parts of watersheds with similar morphological and soil properties.

The poster illustrates how to prepare data for delimitation as well as successive steps of the process carried out in GIS environment. Delimitation is based on digital elevation model (Fig.1) – DEM (grid form) and stream network (vector form).

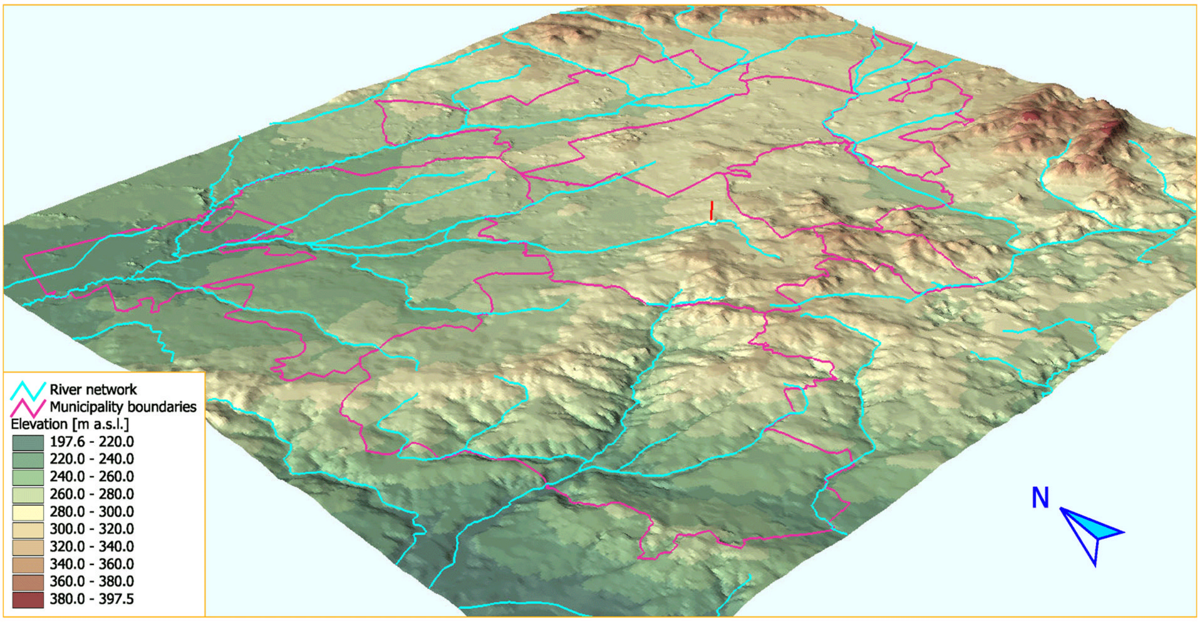

Fig. 1 DEM of the Tarnowskie Góry Megasite

The methodology includes several subroutines. The first one is correction of stream network topology – stream vectors must have a proper turn from spring to mouth or a border of the map, the map can not contain gaps between segments of stream vectors, vectors must be labeled as spring, mouth or other segment. The second routine is building a point layer based on stream network containing altitude information. The next step is building a grid layer which represents the altitude of streams – the altitude must decrease from stream to mouth. This grid is used to correct the numerical model of the terrain. The next correction (on DEM mixing grids and stream network) includes filling the sinks which should have the outflow. On such prepared data final routines[1] computing the flow direction and flow accumulation can be done. This information is used to obtain a set of watersheds.

Watersheds are described with following parameters:

Area - area [m^2],

Perimeter - perimeter [m],

Swat_name - names,

Wat_ID - code of a watershed along with hydrological map of Poland (1,2,3 order),

Swat_ID - code of watersheds of lower order,

Area_km2 - Catchment's area corrected with slopes (A) [km^2]

Perimet_km - Catchment's perimeter (P) [km]

Sl_min_prc - Minimum catchment's slope [%]

Sl_max_prc - Maximum catchment's slope [%]

Sl_ave_prc - Mean catchment's slope [%]

El_min_m - Minimum catchment's elevation [m]

El_max_m - Maximum catchment's elevation [m]

El_ave_m - Mean catchment's elevation [m]

El_stdev - Standard deviation of a catchment's elevations

L_max_km - Length of the longest watercourse (L) [km]. The distance from the pour point along the longest watercourse to the catchment's boundary.

L_eqv_km - Equivalent length of the catchment (Le) [km]. The longer side of rectangle which has the same area and perimeter as the catchment.

$Le = (P+(P^2-16*A)^{0.5})/4$ (traditional operator precedence rule is used to show the formula). If $(P^2-16*A) < 0$ then the script returns Le = NIL, i.e. the corresponding cell in the attribute table has no value. $(P^2-16*A) = 0$ applies to a square and $(P^2-16*A) < 0$ to a circle.

L_relat - Relative longest watercourse length (Lr), dimensionless. Large values indicate an elongated catchment or meandering river. $Lr = L/A^{0.5}$.

The map of small watersheds boundaries generated for the Tarnowskie Góry Megasite is presented in Fig.2

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[1] Flow accumulation, flow direction, watersheds delimitation are standard routines of ESRI software – Spatial Analyst. This software was used by authors for Megasite GIS development.

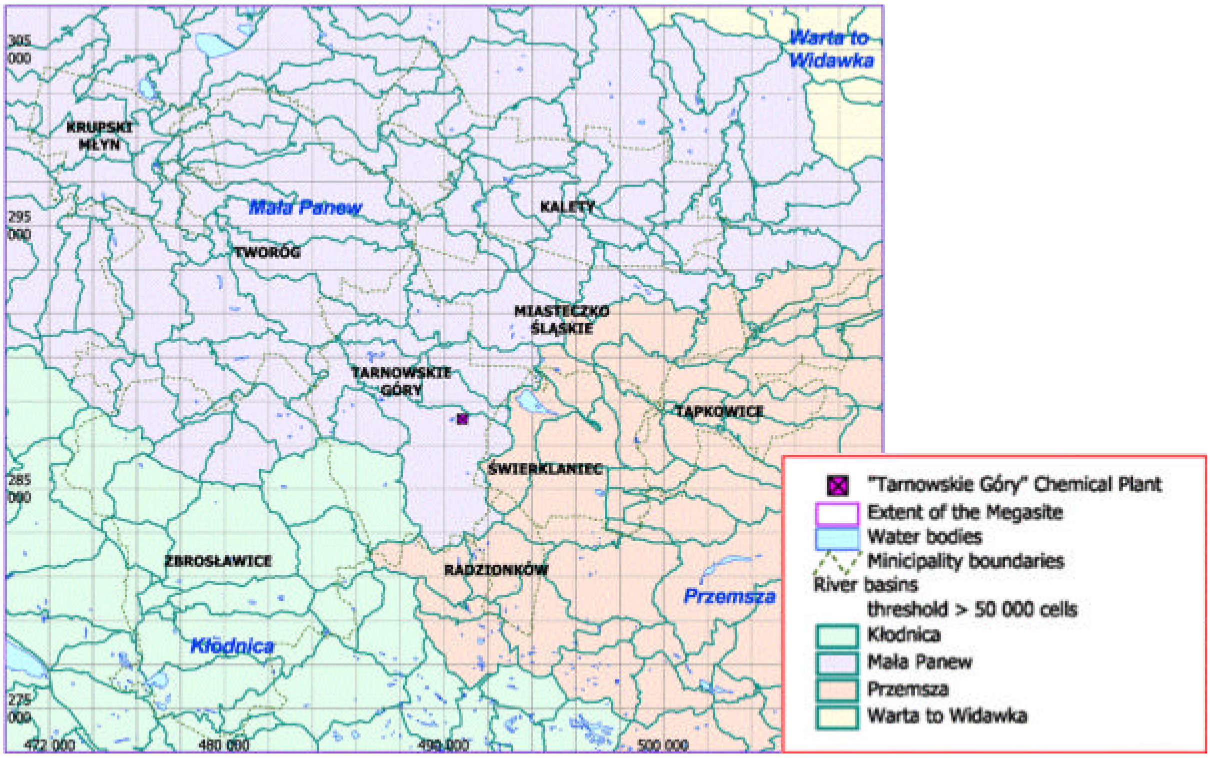

Fig. 2 The boundaries of small watersheds

The watersheds (catchments) are divided into smaller units (hydrological units) by intersection with information layer that contains boundaries of soil units and land use polygons. As a result the hydrologic response units are obtained. The map of land use of the Tarnowskie Góry Megasite is presented in Fig.3.

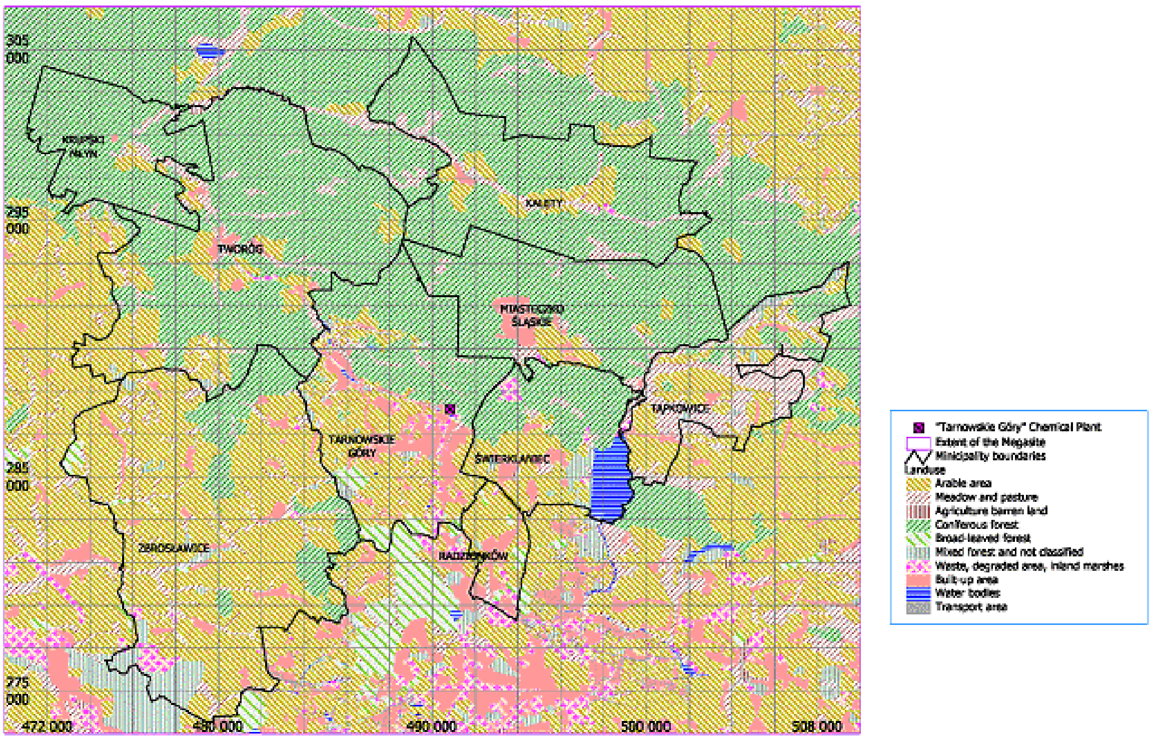

Fig. 3 The land use of the Tarnowskie Góry Megasite

Other solution of the same task is realized by the use of the watershed grid and the grids that describe the parameters of particular soil and hydrogeological layers.

As an example the map of saturated hydraulic conductivity coefficient is presented in Fig.4.

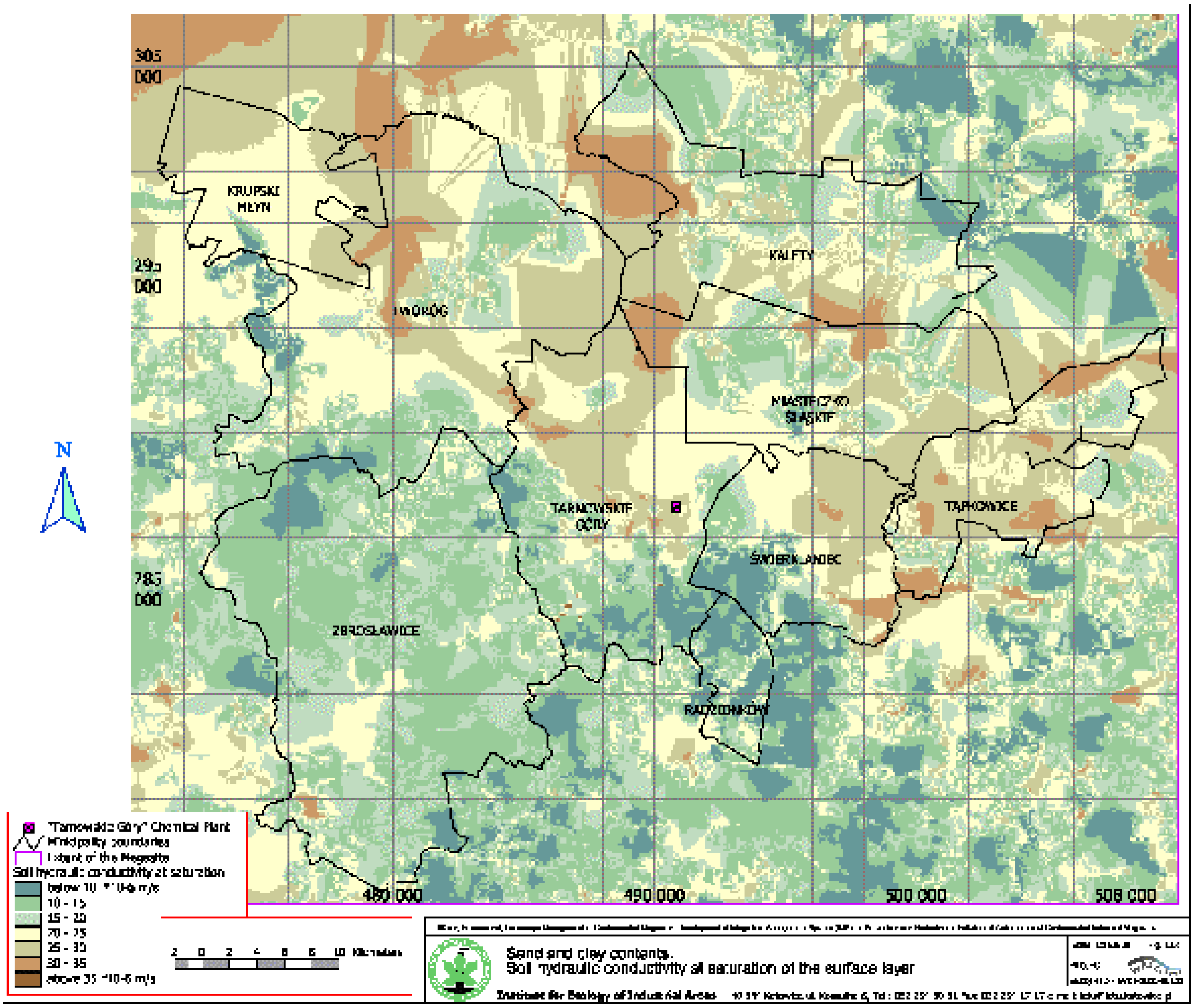

Fig. 4 The coefficient of the saturated hydraulic conductivity

The set of divided watersheds may be used as a base for hot spots clustering. Hot spot clusters can be defined as a set of hydrological units that have similar features and similar sources of contamination.

At the first stage several parameters from different information layers are selected. The selected parameters responsible for horizontal and vertical movement of water within hydrologic unit are used as a first set of grouping criteria.

The one of possible matrix appropriate for this purposes is presented on Fig.5. The thickness and hydraulic conductivity represents vertical properties, slope and area presents horizontal properties. Watershed identity code and neighbourhood of the contaminants source parameters are more comprehensive and responsible for risk weights.

	Hydraulic conductivity	Thickness	Slope	Area	Watershed ID	Neighbourhood of the contaminant source
I soil layer	value	value	value	value	value	value
II soil layer	value	value	value	value	value	value
Quaternary aquifer	value	value	value	value	value	value
Unpermeable layer	value	value	value	value	value	value
Triassic aquifer	value	value	value	value	value	value

Fig. 5 The parameters used to rank the HRU

Clusters are found with help of standard routines such as min-max and hierarchical clusterization. We postulate that for members of the same cluster the same environmental management routines should be used.

THE ROLE OF GIS IN POST-INDUSTRIAL SITE MANAGEMENT ON EXAMPLE OF TARNOWSKIE GÓRY MEGASITE

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The Spatial Information Systems (GIS) are identified with two basic functions:

- spatial data management;
- data visualisation.

Other functions, related to environmental quality management are not observed so frequently. These are:

- influence on information type and source selection;
- GIS role as a data analysis environment;
- possibility to create new information;
- development of spatial environmental and economy models.

Less frequently recognized characteristic of GIS is a synergy among GIS development and capability to make decisions in the field of environmental management at more and more complex relationships between environment and economy.

Water and land management at such complicated objects as the so called MEGASITES is a subject of investigations undertaken within WELCOME Project realized under the 5th EU Framework Programme.

One of the first Project tasks at all Project pilot objects was connected with delivering a GIS site characteristic. The principle of "learning by doing" used within this Project allows to discover and show the relationship which exists among the degree of GIS development and decision making capability.

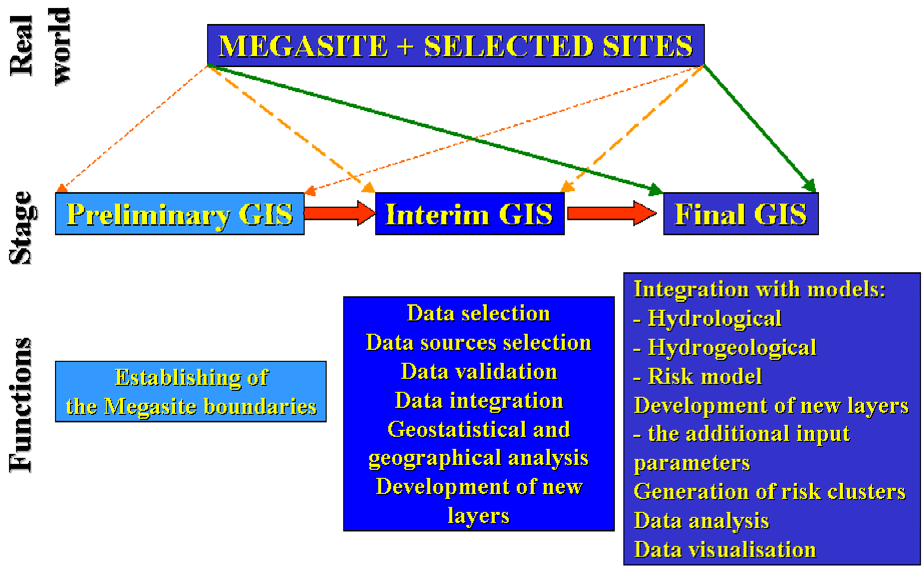

Fig. 1 Scheme of the Megasite GIS development

The role of GIS in the development of management system was presented using examples taken from a Polish pilot study area in Tarnowskie Góry.

As a Polish study area in the WELCOME Project the region of old mining of Zn-Pb ores was selected. The main site of this region is a chemical plant producing different assortment of inorganic chemicals including white pigments „Lithopone" for paint production.
At the very beginning the boundaries of the Megasite and the object from the point of view of a spatial management system were a little bit fuzzy.

It resulted from a preliminary definition of Megasite that assumes that Megasite is an area with many sources of surface and groundwater contamination which emit a number of different contaminants and this state as well as the extent of water pollution is so big that currently available reclamation techniques and economical possibilities are insufficient to satisfy water quality standards.

It means that the definition assumes also, that there already exists some information basis which allows, with bigger or lower uncertainty, to give an answer using criteria formulated in the Megasite definition. And indeed, the existing recognition of environmental problems allowed to point out an area located NW from Katowice town as the above-mentioned pilot area.

The problem appeared, however, when the same answer was to be given, within the task of WELCOME Project, with accuracy requested by spatial information systems.

The problem was solved by analysing legal status and information resources of the information systems existing in Poland.

Strategic management of water resources in Poland is realised by Regional Water Management Boards which are parts of the state administration. The management is performed on the level of large watersheds and main groundwater basins. Management of groundwater contamination sources, which includes industrial areas and brownfields, is the responsibility of self-governments and is realised on a district level (poviat). Quality assessment of particular elements of the environment (water, air, soil) is made by Environmental and Sanitary Inspectorates. The analysis of regulations, the fact that the problem of Megasites is within the competence of two different authorities, as well as results of information resources query show that the Megasite boundaries should be agreed with district (poviat) boundaries despite the fact that districts usually have no spatial information systems at all.

Basic properties of the preliminary spatial information system (GIS) that has been used to solve the above-mentioned problem are presented in Fig.2.

Fig.3 presents relationship between participants of land management process and those responsible for water management. It can be noticed that these relations are complex in nature and as such require almost continuous access to different types of information.

Fig. 2 Preliminary GIS

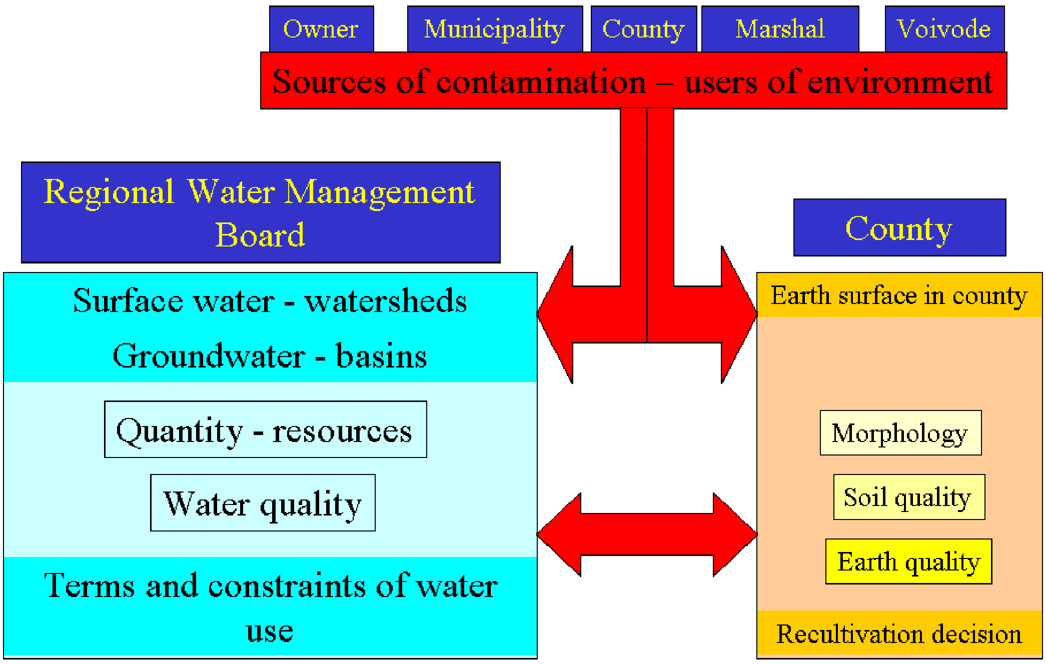

Fig. 3 A general overview of water and land management in Poland

Functions of GIS were much better exposed at the stage of identifying resources of a future spatial information system concerning the Megasite.

The environmental quality management requires good and reliable information on:

- emission sources;
- environment in which contaminant migration is observed;
- good characteristic of receptors.

As good information we assume the information that satisfies quality standards resulting from admission within system of a particular scale – i.e. spatial and temporal resolution as well as frequently underestimated thematic resolution.

In Poland, in hydrogeological models used in strategic management – on the level of a groundwater basin – the most frequently assumed temporal resolution is that of one year. In hydrological models, resolution of one month is introduced with an average daily state simulation option. The most advanced models introduce temporal resolution on the level of one hour (e.g. in ESWAT software).

Spatial resolution varies and is connected with the assumed scale. For example, a digital elevation model of Tarnowskie Góry Megasite was realised with a resolution 50x50m but the first realisation of hydrogeological model was developed with a resolution 500x500m and in some places with resolution 200x200m.

Thematic resolution of GIS is directly related to the assumed functions and types of models to be implemented. A number of model input parameters can serve as an example. Simple models require the presence of a small number of thematic layers. In more complicated models the quantity of information layers increases. In the risk assessment model which takes into account for example the intake of contaminants by soil ingestion (“pica” phenomenon – common children behaviour) it is necessary to provide information on contaminant contents in topsoil – thus the necessity of sampling the layer of 0-2cm or 0-10 cm arises. The recognition of the capability to emit dust by the topsoil is the condition for incorporating the inhalation pathway into the model. In such a way the thematic resolution can be directly translated into the quantity of attributes in an information layer and the quantity of information layers.

Due to the variable accuracy of the available or potentially accessible spatial characteristics the development of Megasite models requires the introduction of at least two different resolutions. One for the whole Megasite and the other (more detailed one) for the individual site. It is the task of GIS to provide the coherence of data of such different characteristics.
The GIS that is filled with such information is a very comprehensive system.

Future application of the system determines its resources. Within the WELCOME Project a risk driven Integrated Management System is developed. It means that a general conceptual model of risk assessment analysis implemented for the investigated area will decide on information resources of GIS. The model is presented in Fig.4.

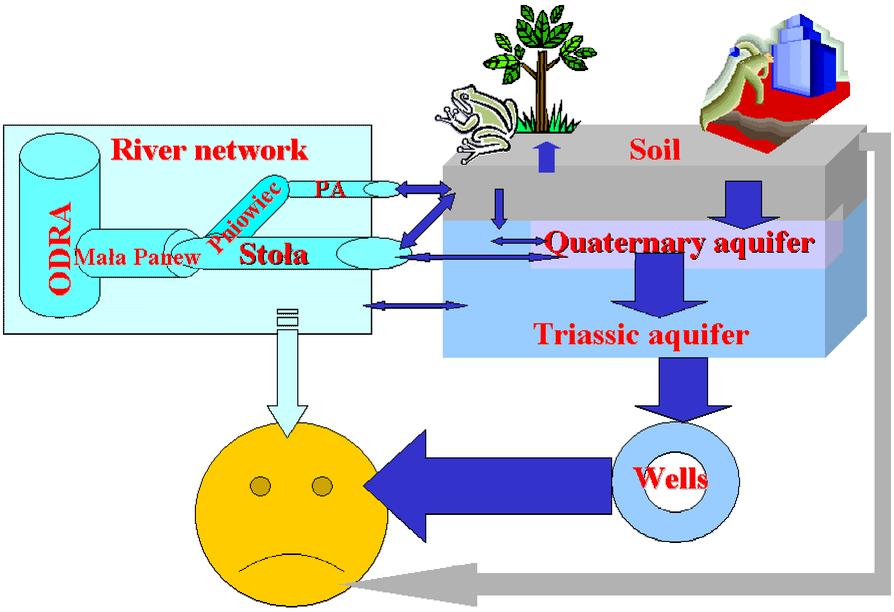

Fig. 4 Conceptual model of the "Tarnowskie Góry" Megasite

This model became a basis for integrating a number of information layers within GIS, as well as for developing a set of new information layers, each of which constituted a unique challenge for authors of GIS description of the Megasite.

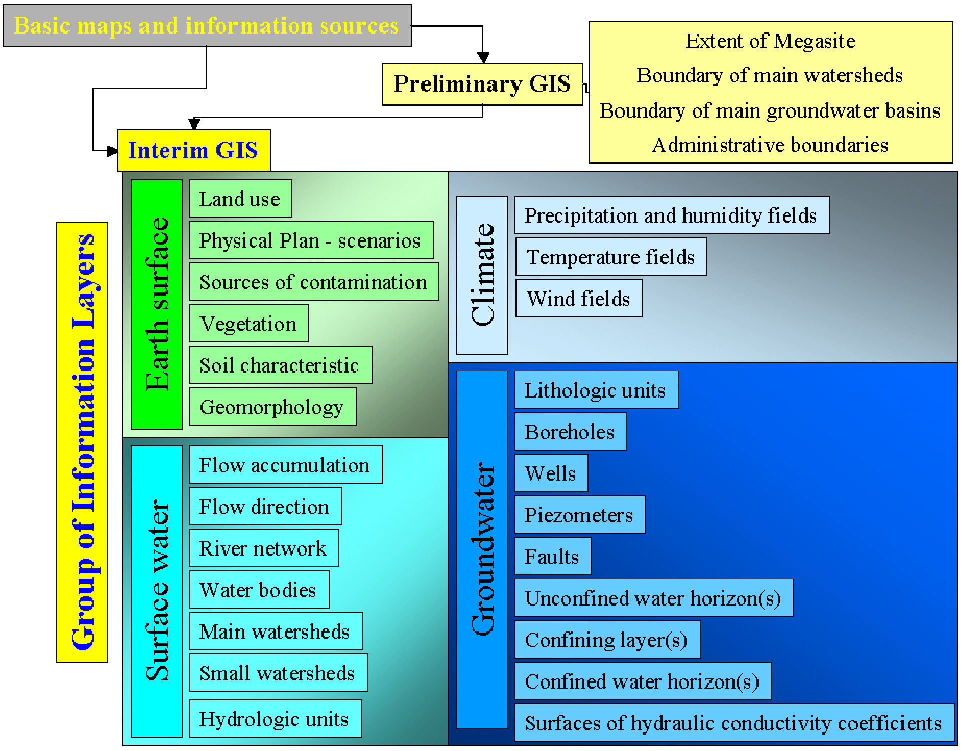

Fig. 5 General scheme of WELCOME GIS development

Two basic functions used at the stage of interim GIS development were as follows: capability to link the information from different sources and capability to analyse the errors borne by the information introduced into the system. These GIS features allow for a critical review of available information and assessment of information sources. The lack of consistency of available data results probably from many reasons. As the most important, the following can be mentioned :

- different age of information;
- differences in scales and differences in used principles of data generalisation resulting from them
- lack of spatial verification of data served by different sources which resulted in the necessity of field verification of a large portion of data.

However, the most serious reason resulted from the fact, that the older information systems were GIS based only in a small degree and in the best cases identified GIS with a cartographic image in numerical format.

The best information, that demanded the smallest workload during integration originated from the existing spatial information systems. In the case of Tarnowskie Góry Megasite these were: the GIS of Silesian Voivodeship, Tarnowskie Góry Town and internal GIS of the Institute for Ecology of Industrial Areas. Integration of information from other sources was extremely time-consuming.

Within the frame of interim GIS implementation, several new information layers were developed. These layers bridge the interim and final GIS, e.g.: information layers that include the values of filtration coefficient for first (0-50 cm) and second (50-100 cm) soil layers for the entire area of the Megasite or information layers on key structural surfaces of the hydrogeological model. Incorporation of data on the network of old adits and galleries into the system along with showing its correlation with the water circulation system in orogen allowed to set up a working thesis about the potential to use this network, after appropriate adjustment, for the purposes of protecting Triassic groundwater from the inflow of contaminants from land surface.

Additionally, incorporating information layers on population number and distribution facilitates automation of health risk assessment.

Integration of over 90 information layers in the system ensures its capacity to calculate a number of new information layers which include input parameters for a number of specific models with the most important ones: hydrological and hydrogeological models.

It is expected that these models as well as the health risk model will be integrated in the final GIS dedicated to the problem of land surface and water management at Megasites. This will allow transforming the present GIS from the analysis tool into a tool for simulating basic phenomena taking place at a Megasite.

The final GIS should provide the following information:

- spatial ranges of phenomena taking place at the analysed site,
- determine the time of contaminants spread in water;
- effects of land use change;
- effects of reclamation techniques employed.