Sustainable Contaminated Land Management: a Risk-based Land Management Approach

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Abstract
Contaminated land policies in the European countries are converging. The major trend in policy development is to address environmental issues and spatial planning issues simultaneously. Efforts to develop such an integrated approach have resulted in a shift in attention of policy makers from the assessment of problems to the formulation of solutions that will meet the needs of society. Risk assessment is now widely used to assess potential human health and ecosystem health problems. Based on the principles of risk management, the broader concept of sustainable contaminated land management has been developed. This concept stresses the importance of sustainable solutions, which will restore the usability and economic value of the land. These solutions can be characterised by three elements: risk reduction, protection of the environment and reduction of aftercare. The first two describe the environmental goals in relation to land uses and functions and resource protection, including the spatial planning aspects. The third describes the way these goals should be achieved.

Key words: risk management, risk assessment, contaminated land, CLARINET, sustainable land use

INTRODUCTION

Making decisions about risk assessment and sustainable solutions for contaminated land problems can be quite complex. A conceptual framework for sustainable management of contaminated land is considered necessary to organise this decision-making process. **'**Risk-based land management**'** as described in the present paper is intended to fulfil this role. The present paper was originally intended to provide guidance for the CLARINET Concerted Action. As a result of discussions in CLARINET the conceptual framework evolved into a general vision on developing contaminated land policies in EU countries. The common ground in these policies is increasing with their stronger interaction with spatial planning and water protection and their longer time perspective of sustainable environmental management.

RISK-BASED LAND MANAGEMENT

Risk-based land management looks quite similar to expressions like *risk-based site management*, which are also often used in the context of soil contamination, for instance at industrial sites. However, for CLARINET's purposes the meanings 'risk', 'site' and 'management' need to be broader, covering the full range of contaminated land problems for which regulators and decision makers are responsible. To highlight this, the word 'land' is used instead of 'site'. Risk-based land management in the CLARINET sense must therefore be considered as a general strategy and **not** as a practical implementation of existing protocols such as the RBCA (1995) or CONCAWE (1997) system, which apply to individual sites.

The implementation of risk-based contaminated land remediation and management is restricted in some countries to what is often referred to as historic pollution, i.e. legacies from the past. Policies implemented, for example, in the UK, The Netherlands and Germany, consider new pollution due to negligence differently. All such pollution has to be removed, because it could have been prevented. The difference in approach between *historical contamination* and *recent contamination* is a political choice – it does not imply that the science of risk assessment cannot be applied for pollution caused by recent activities.

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The three building blocks of the concept: ***risk***, ***land*** and ***management*** need to be defined in view of their use in this paper:

- **Risk**[1] describes the adverse environmental effects of contaminants (human health, ecosystem health, impact on aquatic environment and water resources and the socio-economic consequences of poor soil and groundwater quality). In order to make contaminated land economically viable again we may restore the quality of soil and groundwater by risk reduction. For a full discussion see Ferguson *et al.* (1998) and Ferguson and Kasamas (1999).
- **Land**. The dictionary definitions of '*land*' include: 'the solid portion of the earth's surface'; 'the ground'; 'the soil'; 'a tract of country'. In the context of this paper '*land*' will be assumed to be a bounded area. For example, this area could be a single industrial site, or it could be a region such as municipality. '*Land*' as such is managed (see below). The manager of land, for example, may be the owner or user of an industrial site or a municipal authority. The area involved may be large, possibly involving a number of current or planned land uses.
- **Management** is a set of activities involving decisions about assessment, remediation, land use restrictions, monitoring, spatial planning, aftercare and perhaps other issues. It is a much broader activity than 'choosing a remediation technique'. The manager also has to address issues such as meeting the needs of sustainable development, registration, monitoring and aftercare, and to define the best solution strategy.

CLARINET's general approach is that risk-based land management has to be a framework for the integration of two assessments:

- **The timetable for remediation**

  Priority setting based on current risks and society's needs to change the use of contaminated land;
- **The design of the solution**

  The best strategy to meet all requirements in a sustainable way, including environmental side effects, available space and facilities, local perceptions and other issues.

1. The definition of risk used here is a general and policy oriented umbrella term for the actual and potential adverse effects of contaminated land. A formal probabilistic definition of risk is 'the probability that a given adverse effect will occur'. This definition may be applied to some human health effects of contaminated land, but other effects are not probabilities, they are actually occurring. In that case the term 'damage' would be more appropriate.

Before elaborating further on the interplay between risk, land and management in risk-based land management, this paper briefly describes CLARINET's thinking about contaminated land problems. This is followed by the introduction of the 'design of sustainable solutions' which discusses the collection of issues that need to be addressed when designing contaminated land management solutions. These solutions should guarantee that the land is suitable for its use, and that the solution is sustainable from an environmental and socio-economic point of view. Finally this paper will discuss the weighing of costs and benefits of various solutions from this perspective.

Contaminated land solutions are mainly discussed here at a strategic level. However, to put strategies into practice, the operational details of treatment, monitoring, aftercare and other risk management techniques (containment techniques for instance) also have to be addressed on a site-specific basis.

CONTAMINATED LAND PROBLEMS AND SOLUTIONS

Contaminated land problems can be viewed from two policy perspectives. Polluted sites that endanger human health or ecological health are generally considered as an environmental problem. On the other hand derelict land that does not cause any immediate risk may be considered as a spatial planning problem. National policies for contaminated land used to depend to some extent on the way that soil pollution problems were first perceived (Visser 1993). Recent developments in contaminated land policies in the European countries tend to lessen the initial differences and have much in common. The major trend in policy development is to address environmental issues and spatial planning issues simultaneously. Efforts to develop such an integrated approach have resulted in a shift in attention of policy makers from the assessment of problems to the formulation of solutions that will meet the needs of society.

Current approaches focus on sustainable solutions, which will restore the usability and social and economic value of the land. These solutions can be characterised by three elements; the first two describe the environmental goals including spatial planning aspects, and a third describes the way these goals should be achieved.

1. *Fitness for use*

   This depends on reducing human health risks and ecological risks as necessary to permit the safe (re)use of the land and is focused on quality requirements of the land for uses and functions.

2. *Protection of the environment*

   This can be achieved by preventing the dispersion of pollutants to the surroundings. This is not an issue that only depends on the uses and functions of the land itself, but may also be dependent on the uses and functions of the surrounding land. Moreover the way the 'dispersion risk' is addressed may be different from risks under the 'fitness for use' heading. For example preventing further spreading of pollution by surface water and groundwater may be seen as a form of risk reduction, but the interpretation of risk in this case is more than mere toxicological risks. Environmental protection is also protection of soil and water as a resource, which means that generally accepted preventive principles like the *precautionary principle*[2] and the *stand still principle*[3] have to be applied. In other words, a solution that does meet the fitness for use requirements is not a good solution if it creates potential problems for the future in surrounding areas. Environmental protection of soils as a resource may also lead to policies favouring redevelopment of brownfields over greenfields.

3. *Reduction of aftercare*

   If a solution is chosen which leaves immobile or inaccessible contaminants in the soil there is a need for aftercare. Monitoring and control may be necessary. Sustainable solutions minimise the burden of aftercare. Endless pump-and-treat solutions or containment walls that require control and maintenance forever may achieve fitness for use and prevent pollution of surrounding areas, but may be less desirable in view of the amount of aftercare required.

In the UK, the three goals mentioned above are jointly described by the term '*suitability for use*'. For the purpose of CLARINET it may be more appropriate to consider the three components separately.

DESIGNING A SUSTAINABLE SOLUTION

Over the past 15 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. Choices are no longer limited to 'dig and dump' versus containment. Moreover it is realised that there is no universal best solution. Each solution has its advantages and disadvantages, which depend on the quality requirements for the land in the context of risk-based land management, as well as a wide range of other factors and requirements, such as:

- the physical nature of the land;
- its (envisaged) use(s);
- its impact on water resources;
- neighbour considerations;

and many more. These factors and requirements vary from one situation to another, and hence the availability and appropriateness of solutions needs to be determined on a site-specific basis.

This complexity generates a need for decision support tools, which may vary from straightforward information about the pros and cons of various options to formalised weighing systems. The most important issues the risk-based land manager has to address in order to assure the sustainability of the solution will be discussed below under the following headings:

- risk reduction requirements;
- land use related requirements;
- spatial planning requirements;
- management requirements.

RISK REDUCTION REQUIREMENTS

Risk reduction at the source, the pathway or at the receptor?

Risk is generally considered as the result of a process where some potential hazard (a toxic substance or other agent) could lead to an adverse effect in the 'receptor' (people, animals and plants, ecosystem processes, water resources and buildings). For this process to operate there must be a connection (*a pathway*) between the potential hazard (*the source*) and target for protection (*the receptor*). So theoretically risk reduction may be achieved by removing the source, breaking the pathway and/or by removing the receptors. Current practice shows a preference for a source-oriented approach. This may involve removal of polluted soil and groundwater, degradation of the contamination itself or changing the bioavailability[4] of the contamina-

2. **Precautionary principle.** 'In situations where serious or irreversible damage is likely, cost effective preventive measures must not be postponed until a full scientific proof can be given' (translation from Dutch text of the resolution of the Rio conference in 1992).

3. **Stand still principle.** The state of the environment should not get worse due to 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.

4. Note: this is not source *removal* but a form of pathway interruption that is local to the source area, a change in the nature of the source term.

tion. The latter approach might also be considered as a form of 'path' breaking.

Changing the bioavailability as a risk reduction method may be quite difficult; it requires much knowledge about the current and future behaviour of contaminants in soil and groundwater and may be difficult to control and monitor by the managing authorities.

Pathway breaking is usually achieved by placing a physical barrier between the source and the receptor. This may have consequences for the use of the land, for example, restrictions on use, or the presence of monitoring installations. Other methods include containment through groundwater pumping (and treating) or 'active containment', for example reactive barriers for the removal of certain contaminants from groundwater flows.

Conversely one may restrict the use of the land to avoid some pathways. Because the source is not eliminated it is generally felt that the need for monitoring and aftercare is greater than with source removal approaches, especially if physical barriers are used. The restricted use of the land is much easier to control and monitor, so aftercare will be less. That may be the reason why current approaches favour the removal of the source in relation to the current or intended use of the land.

Removal of receptors is also possible but is less likely to be applied as a sustainable long-term solution. For human health risks, this would imply the evacuation of the site, which is only a realistic option in emergencies. In an approach aiming at revitalising contaminated land, evacuation is not an option – on the contrary, evacuation leads to more dereliction, the problem that was supposed to be being solved. If the risks concern the extraction of drinking water one may move the extraction well or choose to treat the extracted water. This is however never considered as a 'preferred option' in view of drinking water safety considerations and public perception.

Slow extensive[5] remediation or fast intensive approaches?

Until some years ago the treatment of contaminated land was based on civil engineering approaches aiming at maximum risk control (excavation or containment of polluted soil). From a technical point of view, these approaches are still the fastest way to solve the problem. If there is heavy pressure for the reutilisation of polluted sites, fast remediation is an advantage and is still used for most such sites. However the high costs associated with these methods are also a big disadvantage and were prohibitive in many larger scale redevelopment projects. On the other hand, extensive treatment methods like natural attenuation or *in situ* biodegradation appear less costly at first, but require more time, have less predictable results and may require long-term monitoring and aftercare. These extensive approaches may require monitoring devices, aeration devices or may require a stable underground 'geohydrological climate' which may restrict or prohibit other land uses at the site. In particular one should be aware that in some regions soil and groundwater is intensively used or will be more intensively used in future, involving underground works, tunnelling, and the use of groundwater for the storage of heat. If these activities take place in the same geohydrological system as the area reserved for extensive remediation, the performance of the remediation may be affected. The spatial planning consequences of extensive remediation have to be properly addressed, for instance by registering the area in national or regional spatial planning systems. This is especially important because extensive remediation approaches (like monitored natural attenuation) may require land use restrictions in a region larger than the extent of the contamination over a longer time span.

5. Extensive remediation is a term used to describe less destructive or intrusive remediation techniques, like *in situ* bioremediation or monitored natural attenuation. Intensive remediation techniques are the classical dig and off-site treatment approaches using destructive techniques like burning and intensive leaching. The terminology is borrowed from agriculture, viz. extensive farming (less than two cows per hectare) as opposed to intensive farming (bio-industry).

Certainty versus uncertainty?

In the discussion of source, path or receptor oriented risk reduction it was already noted that some approaches lead to more certainty than others. For instance reducing bioavailability is more prone to scientific uncertainties than excavation of polluted soil. If the remediation is related to the use of the land there may be uncertainties in the definition of the clean-up goal. Insight into the toxicity of contaminants may change in future, leading to stricter or more lenient remediation targets.

Apart from the scientific uncertainties, there may be uncertainties in spatial planning. Will the land use change in future or will it remain the same? Moreover, future land use practices may be totally different to the forms of land use known today. For instance, might current practice in land use related remediation limit future use of land for underground building and infrastructure?

These uncertainties translate into land management problems. The choice is between more stringent source reduction/attenuation which costs more but allows for a wider range of end uses of the land and is less subject to changes in scientific insights, or less intensive and costly monitoring and aftercare schemes.

LAND USE RELATED REQUIREMENTS

Different land uses have different needs. For example, some land uses require direct access to the soil, preventing the use of containment measures like capping with concrete or asphalt. Others may require the preparation of the site for geotechnical purposes, e.g. to support foundations. In some cases, the polluted layers at a site may contain rubble, rubbish and coarse waste materials that have to be excavated anyway. This could place excavation and removal for risk reduction as the cheapest solution. Often in these cases, on-site recycling and reuse of debris may further reduce remediation costs. This has the added advantage of reducing demand on primary aggregate resources.

SPATIAL PLANNING REQUIREMENTS

As already mentioned, changes in current land use and future use of the land may be unanticipated, and very different from current forms of land use. Whether land use will be allowed to change may be incorporated in spatial planning, which may then contain specific requirements for the number of potential uses for which the site should be treated. Apart from issues directly related to land use, spatial planning should also address the subsoil, especially in view of the potential impacts of above ground land use on groundwater and surface water. If a change of land use is considered, then the consequences for the geohydrology and the behaviour of contaminants that may be present must be properly assessed.

MANAGEMENT REQUIREMENTS

In addition to the requirements mentioned above there might be other important management issues like funding mechanisms and communication with stakeholders and the general public which may affect the choice of certain solutions over others. The manager will also have to deal with ‘values’ which it is difficult to express in terms of risk or utilitarian concepts like land use or function. The conservation of a pristine underground environment and the conservation of geologically or archaeologically important sites are examples of this. Moreover, legal constraints may prohibit some treatment and risk management solutions. There is also the question of how the decision-making process is organised. Will it be a dynamic and open decision-making process, involving all interest groups, or can a standard flow chart protocol or mandatory decision support system be applied by a single decision-maker? The conceptual ‘manager’ in the risk-based land management approach does not automatically imply that there is a single decision-maker. In most cases the manager will be the competent national, regional or municipal authority. These authorities will have to act within their mandate of public interest. For industrial sites the owner may be the manager who is allowed to make decisions within certain limits imposed by the authorities. These legal matters are country specific and will not be discussed here.

BALANCING COSTS AND BENEFITS IN A SUSTAINABLE WAY

The previous section shows how risk-based land management needs to meet a variety of requirements simultaneously. However, the cost of remediation work is often an overriding factor in decisions made. It is all too easy to take a short-term view of costs and ignore longer-term financial and economic implications. For example, there can be a negative relationship between remediation costs and costs of monitoring and aftercare. Costs may be immediate and direct, or they may arise indirectly as a result of the time taken for a remediation project, or the use of space by a remediation process. Postponing remediation activities or choosing methods that postpone the actual beneficial use of the land have economical consequences which can be labelled as ‘opportunity costs’.

As already discussed there is increasing interest in low input ‘extensive technologies’. Yet it can be very hard to compare directly the overall costs of intensive/rapid solutions, which may have high and rapidly incurred costs, with the large investment in terms of space, time and monitoring of extensive solutions. Indeed the comparison can be further complicated by accounting conventions, and the desire to avoid financial ‘pain’ today, which can be postponed or factored into the future.

In practice, optimal solutions are likely to involve a mixture of approaches. An interesting possibility is to combine a fast acting temporary measure with a longer term extensive treatment to provide an optimal balance of risk management, maximising wider environmental merit and limiting costs.

Interestingly, until comparatively recently the role of the various properties of soil in risk management have been ignored, or at least little strategic thought has been given to their systematic exploitation. The soil environment has some interesting characteristics, which may help in reducing the risk. Soil is a stable and spatially structured living environment. It has a natural capacity to act as a barrier, which can be used in containment approaches and it has a natural capacity to biodegrade substances. If these natural capacities can be used the costs of remediation solutions will decrease.

The use of the natural capacities of soils in remediation or contaminated land management solutions will have to meet the general sustainability requirements of soil protection. This implies that the use of the soil as a containment device will have to meet the same requirements as other containment devices such as waste disposal sites. Sometimes contaminated soil with immobile pollutants is reused as filling material under roads or other constructions. In that case the reused soil should meet the requirements for soil protection of building materials.

Concerning the use of biodegradation, an important policy issue has to be addressed, especially with regard to groundwater. One has to reconcile the temporary use of groundwater as a 'treatment medium' or the aquifer as an '*in situ* biological treatment plant' with water protection policies and regulations. Groundwater is generally considered as a valuable resource that has to be protected. Discharges of hazardous substances in groundwater are prohibited. According to some parties, the use of natural attenuation will be impossible as long as groundwater is protected as a resource.

CLARINET's view is different. According to CLARINET the protection of groundwater and surface water resources does not necessarily prevent the use of soil or groundwater as a culture and treatment medium as long as these resources are used in a sustainable way. In agriculture for instance, the use of pesticides that degrade in soil and groundwater is considered acceptable. If the application of certain substances in groundwater to stimulate natural attenuation is temporary, of short persistence and has negligible long-term effects on the quality of the groundwater, it should be acceptable from a soil and groundwater protection point of view. The same may hold for small-scale dilution and dispersion of the polluting substance during its degradation. It is up to the policy makers to find the right balance between contaminated land remediation and water protection in these cases. Together with scientists they will have to formulate scientifically valid criteria for sustainable use of soil and groundwater in extensive remediation projects. Some of the requirements are already apparent:

- biodegradation has to coexist with surrounding land uses;
- the underground geohydrological 'climate' needed for optimal results may lead to restrictions in land use over a larger area;
- spatial planning, which mainly addresses the surface of the land may have to extend into deeper layers.

Further discussion on the relation between soil protection and soil remediation in contaminated land management is needed, especially concerning extensive remediation approaches.

CONCLUDING REMARKS

In contrast to water and air, land was the latest part of the environment to be addressed in environmental policy. Until now contaminated land has been treated as a series of *ad hoc* problems only. When problems were solved by appropriate technologies, the land did not seem to exist any more from an environmental point of view. As experience has shown in other environmental fields, a mere problem-oriented approach will not automatically lead to a sustainable use of environmental resources. The total environment, including soil and groundwater has to be managed in a sustainable way. The vision of the CLARINET Concerted Action may be considered as a step forward towards an integration of sustainable soil quality and land use management in environmental policy.

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