Source Management - Findings of the May 2000 NICOLE Workshop

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Abstract

This paper sets out an overview of what constitutes "source management" based on papers submitted to a workshop held by NICOLE, the Network for Industrially Contaminated Land, held in Finland in May 2000. The principal conclusions of this workshop are that:

- Risk based decision making is the best available paradigm for dealing with the problems posed by land contamination. Its advantages are that it is systematic and objective, and it provides a consistent and defensible basis for considering uncertainties, discussing options and making decisions. However, a number of challenges face practitioners and users of risk assessment and risk management, in particular: public acceptability; dealing with uncertainty; validation and the development of practical robust and agreed tools.
- In addition to risk management, sustainable development should be explicitly considered in all remediation decision making for source management.
- Early and effective communication with all legitimate stakeholders is recommended to ensure the earliest and widest acceptability of any decisions reached.

1 Introduction

Several billion EURO are spent in the EU each year on the remediation of land affected by contamination. It is an important goal from all perspectives that this money is spent wisely and appropriately. Two European networks, supported by DGXII of the European Commission have been striving to provide the means by which this goal can be realised by providing technical support to promote best practice, a forum for the exchange and development of the state-of-the-art, the identification of research and development needs, and the development of collaborative projects. These networks are: NICOLE, the Network for Industrially Contaminated Land in Europe; and CLARINET, the Contaminated Land Rehabilitation Network For Environmental Technologies in Europe. NICOLE has published several joint views on important contaminated land issues with CLARINET, and its predecessor CARACAS (1998 & 2000) In particular these have highlighted the importance of a risk based approach to contaminated land management (explained below). In May 2000 CLARINET and NICOLE held back to back meetings in Espoo, Finland. The focus of the NICOLE meeting was a workshop to develop a particular aspect of the risk based approach: *source management.* The workshop was attended by 78 contaminated land practitioners and experts from 13 countries. Its aim was to find a consensus view on the best way of managing sources on contaminated sites, in particular where removal of that source was not feasible.

This paper sets out an overview of what constitutes "source management" based on papers submitted to the workshop. The paper then sets out the findings of the workshop regarding best practice for source management, as well as a number of broader themes that emerged from the discussions.

2 What is Source Management

Source management is a term which has been coined by Exxon and is really practically, rather than conceptually, derived (Bill Hafker, Exxon)1. He described source management as *how to deal with contamination sources on a particular site*. These sources may be relatively "intact", i.e. no remedial intervention has yet taken place, or be residues left after an initial intervention. Initial interventions might include one or more of the following:

- Some form of emergency source removal or containment activity;
- Some form of emergency action to protect receptors; or
- A source treatment or removal that has left residual contamination behind.

Source management applies to many types of contaminated site. This paper focuses on source management as an issue for sites contaminated by petrochemical and manufacturing issues. The workshop itself included papers about former coal mining sites and sites contaminated by radio-nuclides (Klaus Simsch, Deustche Steinkohle, Germany; and Matthew Randall, BNFL, UK), but the majority of discussions focused on problem sites of the petrochemical and manufacturing industries.

3 The Risk Management Perspective

The workshop heard several presentations about source characterisation and risk assessment (from Matthew Randall and Andrew Patsky, BNFL, and Phil Irving, URS Dames and Moore, UK).

Remediation is carried out where there are unacceptable risks to health or the environment, assessed in relation to the current or intended use of the land and its wider environmental setting. There are a number of scenarios in which remediation projects are typically initiated:

- To protect human health and the environment.
- To enable redevelopment.
- To limit potential liabilities.

A risk based decision making process for remediation is now the norm across EU Member States (CLARINET and NICOLE, 1998, Ferguson and Kasamas, 1999). In this process, risk assessment and the subsequent step of risk management are intimately related elements that form the basis for a fitness-for-use approach to land affected by contamination. The goal of risk assessment provides an objective, scientific evaluation of the likelihood of unacceptable impacts to human health and the environment. The goal of risk management is to support decisions on risk acceptability for specified land uses and to determine the actions to be taken. In other words, it is the process of making informed decisions on the acceptability of risks posed by contaminants at a site, either before or after treatment, and how risk reduction, if appropriate, can be achieved efficiently and cost effectively [Ferguson *et al* 1998, Ferguson and Kasamas 1999]. In this way, the over riding needs for the protection of human health and the environment can be clearly identified and work prioritised accordingly.

The assessment and management of land contamination risks considers three main elements, as illustrated in Figure 1:

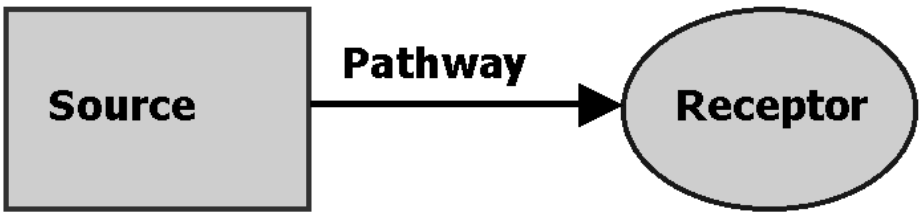
- the source of contamination (e.g. a solvent spill, or buried materials on a redevelopment site)
- the receptor (i.e., a part of the ecosystem that could be adversely affected by the contamination, such as groundwater, human beings, flora and fauna)
- the pathway (the route by which a receptor could come into contact with the contaminating substances).

A hazard exists when all three elements are in place: i.e. a source of toxic substances, a receptor and a pathway for that receptor to come into contact with the toxic substances from the source. A hazard is a situation in which contamination in the ground has the *potential* to cause harm (e.g., adverse health

1 Note: the names and organisations given in brackets refer to oral contributions made at the workshop

effects, groundwater rendered unfit for use, damage to underground structures, etc.) to a particular receptor. *Risk* describes a *quantification* of the likelihood that specified harm to a specified receptor will occur.

Figure 1 A Pollutant Linkage



The presence of all three elements is also referred to as a pollutant linkage. Risk assessment involves the determination and characterisation of such a relationship including for example, delineation of the source, measurement/modelling of fate and transport processes along the pathway, and the potential effect and behaviour of the receptor. A consideration of risk must also take account of not only the existing situation but also the likelihood of any changes in the relationship into the future.

The talks and following discussions for Phil Irving (and Victor Dries in a later talk) highlighted a series of critical issues for source characterisation and risk assessment.

Stakeholder involvement: it is important to identify all of the key stake holders in decision making at an early stage. Indeed it is often prudent to involve them in decisions about what data need to be acquired, not only as peer reviewers of a risk assessment. A variety of stakeholders may play a role in contaminated land decision making, for example: land owners/problem holders; regulators and planners; site users; those with a financial connection to a site; the neighbours to a site including the local community; the consultants, contractors, researchers and vendors involved in designing and implementing the remediation. There is an element of choice in which stakeholders to involve and at which stage to seek their involvement. However, some, for example the regulator, will be an obligatory consultee from an early stage. There is a difficult balance to be struck between who to involve and who not to involve. Involving a larger number of stakeholders in decision making will add to the costs, complexity and duration of decision making. However, involvement may save future difficulties that might be caused by the reactions of aggrieved stakeholders who were not consulted early enough.

Using Pollutant Linkages to Identify Receptors: Cees Buijs (HBG, the Netherlands) pointed out that as well as using the pollutant linkage paradigm for risk assessment it can also be used for prioritisation and to facilitate risk communication. For example, examining pollutant linkages should be used to determine which receptors are truly at risk (to prioritise remedial actions). Knowing the receptors at most risk will also serve to identify the stakeholders with whom communication effort is most important (i.e. the stakeholders who are, "own" or are responsible for the receptors at greatest risk).

Quality of Information for Decision Making: Victor Dries of OVAM (Belgium) in particular drew attention to the extremely variable level of quality of both the models and assumptions used for source

characterisation / sampling and risk assessment and in particular the "human" dimension of the services provided by consultants and analysts. His first concern was that, whatever the sampling strategy, it was more than likely that decision making would be based on at best an approximate understanding of the disposition of contaminant sources. His preference was for a tiered approach to sampling where an initial campaign was able to delineate a general view of contaminant dispersal, and successive campaigns provided greater levels of resolution and the ability to focus on particular problem areas. This approach may be more cost effective in terms of the information provided, but it is more time consuming. And time can be money. On-site techniques, such as geophysical investigations and on-site XRF may have the ability to provide a greater number of analyses within a particular cost-time envelope, but are not without limitations. For example geophysical techniques lack discrimination and resolution. On site analyses are hard to validate. Victor Dries also pointed out that "classical" laboratory data was subject to a high degree of variability. He presented data from a "round robin" of organic analyses of standardised samples sent to a number of different laboratories. The data returned for each sample analysis varied by up to two orders of magnitude. As a result of these studies a stringent quality control procedure has been initiated in the Flemish region of Belgium, where the regulator (OVAM) will only accept site analyses for decision making, if these have been carried out by laboratories which it has accredited itself. However, more than 60% of the analytical services applying for accreditation have been unable to reach the required level of analytical data "quality".

The problems posed by heterogeneity to sampling are not only a problem for the solid materials in the ground. Professor Teustch of the University of Tuebingen (Germany) stressed that for most contaminated aquifers the distribution of uncontaminated water and contaminated water was highly discontinuous within the subsurface, with dissolved phases existing as discrete thin layers within the aquifer. He questioned the ability of most monitoring wells to provide sufficient resolution to understand the depth profile (let alone the area profile) of groundwater contamination. In effect many monitoring wells average groundwater contamination across the depth of their screens. This not only means that the contamination is not localised in one dimension, but that maximum groundwater concentrations tend to be under-estimated.

Phil Irving drew attention to the lack of consistency in approaches to risk modelling between different countries, where different data sets (even for toxicity data) and assumptions were used. He suggested that harmonisation, at least of technical information such as key datasets, should be possible. This is principally a task for the regulator community. NICOLE and CLARINET are collaborating on a comparative study of risk assessment procedures from different countries (e.g. Netherlands, Sweden and UK) for a specific site to investigate the practical impact of these differences in national approach. He also highlighted how risk assessment models varied in their complexity, costs and use of time.

Victor Dries explained that the variety of models, approaches and assumptions used in risk assessment was seen in Belgium as a further source of uncertainty. Consequently, Flanders has adopted a single system for use in all contaminated land decisions in the region. He also raised the sensitive topic of the skill base available to many site investigation and risk assessment/management consultancies. He wondered whether the services provided always reflected technical excellence, particularly given the competition on costs and time constraints typical for many projects. This assertion must however also be balanced by considering what service providers are asked to supply, and at what cost. Cees Buijs (HBG, the Netherlands) pointed out the obvious in that a customer only gets what they pay for. Furthermore, it is quite possible for customer requirements in a specification, other than cost limits, to interfere in the delivery of service quality. For example, requirements to use poor site investigation data, unsuitable models and assumptions, comply with unsuitable standard techniques can all affect a service provider's ability to deliver quality, as indeed can a poorly drafted specification.

Uncertainties: Phil Irving stressed the need for the use of sensitivity analyses to test findings and assumptions given the inherent uncertainties in risk assessment. Uncertainties arise from:

- The interpretation of contaminant data, typically so-called "total" concentrations, where environmental effects are dependent on factors such as speciation and spatial and temporal effects;

- The characteristics of the subsurface (see later discussion);
- The reliability of identification and characterisation of pathways;
- The disposition of receptors and how that might change in the future;
- Fate and transport models (which model should be selected, and how should it be validated);
- Exposure assessment; and
- Toxicology.

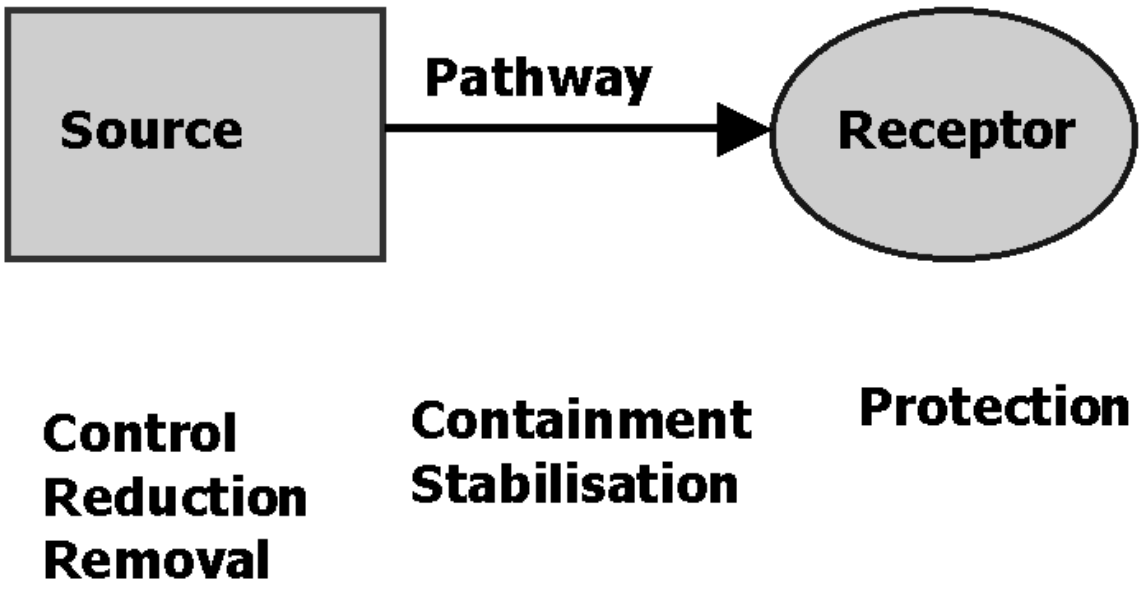
4 Dealing With Pollutant Linkages

Bob Harris of the Environment Agency of England and Wales explained how the pollutant linkage paradigm is also useful for setting out the principles of risk management also in terms of dealing with a pollutant linkage. In simple terms, the risks may be limited by breaking the linkage, illustrated in Figure 2. For example:

- By reducing or modifying the **source** (e.g. by bioremediation of the solvent spill).
- By managing or breaking the **pathway** (e.g. use of a treatment wall).
- By modifying the **receptor** (e.g. by limiting land-use).

Risk management is the art of managing risk so that the hazards posed by contamination are acceptable. Risks should be assessed on a site-by-site basis to ensure that a site is suitable for its designated use.

Figure 2 Risk Management



5 Source Management and Risk Based Decision Making

The first source management decision is to determine whether or not the source (or sources) is manifesting an unacceptable risk, i.e. that it is part of one or more complete pollutant linkages that present an unacceptable probability of a hazard to a receptor. Assuming unacceptable risks exist three risk management options can be considered: reducing or modifying the source, managing or breaking the pathway, or modifying the receptor. The choice and application of these management options will

depend on a variety of site specific factors. Three case studies presented to the workshop by Terry Walden of BP-Amoco illustrated these choices and applications for remediation projects at the Nijmegen Terminal (The Netherlands), Pumpherston Refinery (UK) and Hunxe Refinery (Germany).

In all three cases, risk assessment was utilised to indicate the most practical way forward. At the Nijmegen site, risk to surface water in the surrounding canals dictated either a source removal or containment action but, since the property was being sold, it was more feasible to proceed with source removal. At Pumpherston, offsite migration risk was precluded by channeling the groundwater into a reedbed, while the soil was either stabilsed or biotreated to risk-based standards, making it suitable for re-use as golf course fill. Compared to an initial cost estimate of £50 million to incinerate all the PAH-contaminated soils, BP Amoco spent less than £5 mil on the risk-based solution. And at Hunxe, where active source treatment proved ineffective, natural attenuation (a form of pathway interruption) and receptor use restrictions enabled the land to be re-developed rather than sitting idle.

Nijmegen Terminal	• A small tank storage area (1.2 ha) constructed in 1956 and now sold as an ongoing facility • BTEX contamination • Treatment for "multi-functionality" and groundwater protection *Source Management*: soil vapour extraction (SVE) and sparging, 3 year duration *Risk Management*: source removal
Pumpherston Refinery	• A shale oil refinery over a large area (28 ha) used over a long period (since 1870) demolished in 1960s and replaced by detergent manufacture until 1993 • PAH contamination localised in hotspots and surfactant contamination of groundwater • Treatment to acceptable risk management outcomes for end use as a golf course *Source Management*: in situ stabilisation of materials with high concentrations of PAH, biopile treatment of lower PAH concentration materials, diversion of contaminated groundwater through a reed bed. *Risk Management*: combination of source removal and pathway interruption
Hunxe Refinery	A large refinery operating from 1960 to 1985, with part of the site an ongoing terminal, the remaining land area (80 ha) is to be sold for industrial use, total land area approximately 200 ha • BTEX contamination • Pilot scale tests of air sparging and dual phase extraction had only limited effectiveness at this site • Treatment to acceptable risk management outcomes for industrial end use, free product mostly removed but remaining groundwater contamination resulted in institutional controls (excavations limited near water table, groundwater cannot be used for drinking water and requires ongoing monitoring, retention of liability by BP) *Source Management*: biopiles for solids (26,500 tonnes) and pump and treat for groundwater (27 wells) *Risk Management*: combination of source removal (unsaturated zone), pathway interruption and receptor modification (re-use restrictions)

6 The Effectiveness of Source Removal / Reduction

6.1 Use of *In Situ* Technologies

Presentations on the general application of *in situ* remediation technologies to remove or degrade contamination sources were made by Genevieve Boshoff of Queens University (UK) and Georg Teutsch. While treatments are often described as being primarily for groundwater or for the vadose zone etc, in practice, *in situ* treatment has to offer improvement to the solid and fluid phases of the subsurface. Clearly, in most circumstances the solid portion of the subsurface is static, and the fluid portions (e.g. air or water) can move. In practice this means that these fluids are the vectors of risk along a contamination pathway. They are also the *carriers* for any treatment, treatment agents, or organisms used to effect a treatment within the subsurface (and the nutrients, pH and redox conditions necessary for their activity and growth). The *accessibility* of contamination to a treatment regime is dependent on the ease of access to one or more of these carriers to zones of contamination. This accessibility is limited by the physical properties of the ground environment. The discontinuities in subsurface conditions, which are a function of the complexity and heterogeneity of ground conditions are the main limitation to treatment effectiveness. It is important to understand the differences in scale between the possible interventions, such as flushing and venting, which may operate with wells spaced at distances in the order of metres from each other; and the scale at which treatment interactions take place in the ground environment, which is measurable in µm ($m \times 10^{-6}$). For a treatment to be effective the contamination and treatment regime have to be in intimate contact at the same time.

Once the treatment regime is in the vicinity of the contamination, the contamination's *availability* to the treatment regime may be limited by factors such as: physical/chemical interactions between contaminant substances and the surfaces of the solid phases in the subsurface, contaminant volatility, speciation and/or solubility, and phase differences (e.g. where non-aqueous phase liquids - NAPL's are present).

In most cases the carriers for the treatment regime and the vectors of contaminants along pollutant linkage pathways will be one and the same. Hence the effect of the *in situ* treatment on contamination in the carrier(s) must be in some way more profound than the naturally occurring processes that are moving contaminant substances towards receptors.

In natural attenuation processes that move contamination to a groundwater receptor also have an effect on the reduction of contamination levels in the carrier as it moves along the pathway, both directly through dilution, and indirectly by bringing the contaminants into contact with "new" surfaces where they may be sorbed or degraded by biotic or abiotic processes. In this regard natural attenuation can be considered more a conclusion of risk assessment than an active intervention process, *with one proviso*. Active management takes place: monitoring to assure stakeholders that the envisaged natural attenuation effect is actually taking place.

6.2 *In Situ* Source Removal Versus Pathway Control

Where source removal or degradation is incomplete, even small quantities of contamination can have a profound effect on groundwater quality owing to the relatively low levels substances need to reach in groundwater before rendering it unacceptable. Professor Teutsch questioned the usefulness of attempting source removal from the saturated zone with current *in situ* flushing, sparging and venting technologies on several grounds:

- That the effect is not sufficient to prevent ongoing unacceptable levels of groundwater contamination - removal efficiencies would need to be in excess of 90%, and this is rarely achieved in practice, where removal of 20 to 30% is more usual;

- That the physical (and chemical) processes induced in the saturated zone by removal activities might exacerbate the rate at which the residual material left after treatment is released into ground water;
- That the high costs of *in situ* removal processes are not justified by the risk of failure to achieve an acceptable end result.

Clearly the effectiveness of *in situ* removal actions based on moving a fluid through the soil is highly dependent on site specific circumstances. UK case studies (in London, Manchester, Cheltenham and Surrey) presented by Barry Ellis of Celtic Technologies demonstrated how *in situ* source removal technologies are in widespread use. Observation of effects on plume stability may give some comfort that problems are being remediated rather than exacerbated. Celtic also pointed out that being able to demonstrate the physical removal of source materials, such as NAPLs, from the soil is often of great importance to the site owner and regulator, who perceive this as evidence that "clean-up" is taking place. The attractiveness to regulators of free product removal of NAPLs was also mentioned in a written contribution from Drs Huntley and Beckett from San Diego State University (USA).

Overall, there was a range of views in the workshop as to the general effectiveness of in situ techniques for source removal from the saturated zone. These points of view led to a wide ranging debate about the effectiveness of source removal from the saturated zone as a source management technique. While it was generally agreed that such removal can rarely be regarded as even nearly complete, some delegates felt that partial removal was better than nothing and offered a degree of comfort to regulators and the owners and neighbours of a site. Others felt that this comfort was illusory, and that in many cases partial removal would have no effect on risk management, and indeed had the potential to exacerbate contaminant flux into the groundwater.

Professor Teutsch suggested that a rational view of effectiveness ought to consider the *flux* of contamination entering groundwater before, during and after some form of intervention, i.e. the amount of contamination being dissolved per unit time and volume. Flux is a two edged sword in that increasing flux increases the likelihood of groundwater contamination being unacceptable, but also - albeit over decades - reduces the persistence of the contamination effect. *In situ* removal actions operate on the basis of increasing flux, but often an enhanced flux of contamination remains after the removal action has ended. This enhanced flux of contamination may persist for sometime as complete removal of the source is unlikely to have taken place. The decision about whether or not to carry out an *in situ* removal action should therefore consider whether any possible enhanced level of contamination flux following treatment is acceptable. Professor Teutsch proposed that monitored natural attenuation and, if that was not acceptable, pathway interruption are more practical and more effective means of source management in that:

- There is no risk in exacerbating flux of contamination from the source
- It is likely to be cheaper
- It is likely to be more effective.

The optimum form of pathway interruption is likely to be some kind of "active containment", where the contamination is removed or destroyed by an intervention, but the flow of ground water is not greatly impeded. Examples of such technologies include "treatment walls or curtains", in ground reactive zones, Funnel and Gate™ and 'biobarriers". These presentations show how this NICOLE workshop highlighted differences in points of view between some remediation practitioners and theorists about the likely effectiveness of source removal actions[2].

2 Funnel and gate technology, which relies on directing groundwater toward the gate, has some difficult technical challenges, however. In some field trials the groundwater tended to flow under the funnel. In practice, Funnel and gate technology is mostly applied to chlorinated solvent plumes where the rates of natural degradation are low. For petroleum hydrocarbons, the industry tends to rely more on monitored natural attenuation or biological barriers, such an biosparge curtains or oxygen-release compound curtains, to control plume movement, since the technology is simpler to apply and to adjust as conditions change (Terry Walden, BP-Amoco, Framework 5 Research Workshop in Venice, June 2000.

6.3 Role of Biological Processes *In Situ*

It is important not to overlook the potential of *in situ* biological and abiotic processes for both source control and pathway interruption. Degradation and sorption to surfaces may make the major contribution to the overall "removal" of a source, compared with removal at the ground surface from the extracted fluid, be it air or water. Degradation, whether biological or chemical, is preferable to sorption, if there is a possibility that sorption may be reversed by future changes in ground conditions in a way that might pose unacceptable risks.

Huub Rijnaarts of TNO (The Netherlands) presented a study *of in situ* biodegradation of a chlorinated solvent source (from a dry cleaning plant) in a peat layer in the Netherlands. Experimental microcosm data have been combined with hydrogeological models to provide a prognosis for the likely performance of MNA and interventions to facilitate anaerobic *in situ* biodegradation. Initial pilot scale tests *in situ* have also begun. The contamination comprises both free phase and dissolved solvents. After the removal of free phase product from the source area natural attenuation is estimated to require 20 to 30 years to reduce the plume in the contaminated aquifer. Biodegradation is largely a process that reduces the dissolved phase. Furthermore, the free phase product appears to inhibit degradation of the dissolved phase in the source area. Hence removal by some form of extraction is envisaged as necessary before any subsequent bioremediation or natural attenuation of the dissolved phase. Flushing with "alcohol" is being considered for free product removal, along with injection of an aqueous extract of "compost" to stimulate *in situ* biodegradation. Overall treatment times for the source area (free product removal and bioremediation) are estimated by TNO to be three to five years.

6.4 Implementation Issues

Victor Dries of OVAM, the Public Waste Agency of the Flemish Region of Belgium, made an impassioned call for all practitioners to be aware of the limitations of current risk assessment and risk management tools. Several issues were for him major sources of concern:

- Quality of analytical data (discussed above);
- The appropriateness of sampling regimes used, particularly given the need in many cases to reconcile optimisation of information collection with rapid decision making for remedial action (discussed above);
- The appropriateness and reliability of current risk assessment assumptions, models and methodologies;
- The availability of a sufficient calibre of risk assessment and management expertise amongst practitioners, particularly given the time and budget constraints typical for most projects, in particular the collection of some of the more difficult environmental parameters used to provide the "lines of evidence" that might support monitored natural attenuation.
- The limited effectiveness of in situ source removal activities;
- Concern over the institutional stability of organisations using MNA for risk management, or where risk assessment indicated no active intervention was necessary, or where a long term treatment is employed.
- Mr Dries' preference was for interventions that remove contamination and accelerate environmental remediation, in particular where these were lower input processes.

The question of the stability of organisations was discussed by several delegates. Mr Dries questioned whether many organisations had the management ability and stability to sustain monitoring activity over several decades. In addition, long term management requires the long term maintenance of records, both of problems assessed and decisions made. Perhaps such records might need to be maintained for a couple of decades, perhaps for a century. Mr Dries' view was that over such long periods business activities could be disrupted by major political upheavals, let alone normal business risks.

There was a general view in the meeting that projects were being driven to ever lower levels of profitability for service providers. This poses a significant challenge to the maintenance and development of quality and expertise amongst risk assessment / management service providers. The provision of quality was further constrained by the emergence of many service providers tapping a limited skills pool, multiple tenders being principally decided largely on a cost basis and the inability of many service providers to keep up with the volume of newly emerging information (see Plenary Discussion below). Service providers at the meeting felt that quality was largely in the control of those commissioning services, and that value and effectiveness rather than cost should be the principal considerations. Many problem owners felt that as they were resource limited they had little scope to bear greatly enhanced costs, in fact they required cost reductions.

6.5 Source Management and Water Quality

Bob Harris (Environment Agency of England and Wales) reminded delegates of the significance of water quality issues as driving forces for the remediation of contaminated land. He drew delegates' attention to the Groundwater Directive and the forthcoming Water Framework Directive. An important practical implication of the Groundwater Directive is that where a contaminated site overlies and aquifer that is not contaminated, *only the unsaturated zone can be used to effect an* in situ *treatment*, to avoid any contravention of ground pollution regulations. This consideration is particularly important for deep regional aquifers, but does not hold true where the aquifer itself is contaminated. The forthcoming Water Framework Directive may have a profound effect on the requirement for land remediation. This Directive aims to improve water quality. However, its requirements for surface water bodies, such as rivers, my emerge as a new driver for contaminated land remediation. It is becoming apparent that control of point sources is now largely complete, so further improvements in river quality are more likely to come for the control of diffuse sources. Land contamination is a significant diffuse source for contamination affecting rivers, hence regulatory pressures to improve river quality to reach ecological objectives, may become manifest as a requirement to treat particular contaminated sites, where a linkage to river contamination exists.

6.6 Source Management and Sustainable Development

6.7

Mr Harris also commented on the appropriateness of remediation where regional aquifers were contaminated from many small and diffuse sources, for example aquifers beneath Birmingham in the UK. He pointed out two somewhat conflicting considerations. Firstly, in many cities groundwater levels are rising, a need to control the water table combined with increasing pressure on existing resources, is likely to lead to increasing use of local water from beneath cities, although not necessarily for potable water. This may lead to groundwater quality for these aquifers increasing in importance. On the other hand, individual remediation projects for particular problem sites may be incapable of having an observable effect on the quality of these aquifers, as such a plethora of other sources, and historic pockets of contamination in the subsurface, would continue to exist. In some cases the environmental benefits of a minor reduction in source load from a single remediation project might not be worth the environmental burdens (not to mention the costs) of the remediation activity itself, if groundwater quality was the only driver for the remediation project. This point triggered a discussion about the general need to consider remediation in a broad context of sustainable development, as opposed to a narrow context of specific site objectives.

The majority of delegates agreed that the value of specific site objectives needed to be compared with its broader environmental, social and economic costs and benefits, both to the local community and further afield. However, in certain circumstances site specific considerations, driven by strong regulatory forces, may take precedence over such wider considerations of environmental, economic and social effectiveness. Many at the workshop felt that this was entirely appropriate, given that human health risks were typically the over-riding criterion used to determine risk management needs.

Others felt that while a narrow focus on risk assessment procedures did not necessarily allow the consideration of the potential negative impacts of a remediation project itself , and might not allow a rational assessment of the need for remediation against other spending requirements, for example on education and health.

Reports on Source Management from Syndicate Groups

The workshop included discussions of source management issues across two syndicate groups, one considering inorganic pollutants and the other organic pollutants. Each syndicate considered three general issues:

- How best to manage contaminant sources on a site, in particular whether source removal should always be attempted, and how risk assessment and management tools should be best applied;
- What information is needed to properly address source management; and
- What land management policies have influence over source management.

Report of the Inorganics Syndicate

The removal of the source term is often not feasible or not appropriate for economic, environmental or other reasons. In particular, removal of the source often only transports the problem to another site. The risk assessment / risk management paradigm is seen as the best approach for dealing with inorganic contamination sources. In general, risk assessment tools are more robust for inorganic contaminants, and their knowledge base is broader with a greater level of agreement between different experts, practitioners and regulators. Hence risk assessment is considered sufficiently reliable to underpin decision making. However, communication and involvement with other stakeholder groups, from an early stage, is vital to achieving generally acceptable decision making. It is also important that the decision making is transparent. A particular difficulty is that the risk assessment models themselves may not be transparent (i.e. their assumptions and operations may not be clear to all), and there is some concern that they are not always correctly used by all practitioners.

The risk assessment tools available are of course not yet perfect by any means and several areas for improvement exist.

- There is a need for risk assessment methods to better address the impact of bio-availability and speciation;
- There is a need for common baselines, for example common toxicity data such as tolerable daily intakes (TDI's);
- It would be beneficial to have approaches able to make a prognosis of the long term consequences of leaving contamination in place and how risks might change over extended periods (e.g. over decades).

Report of the Organics Syndicate

Source management must strike the optimum balance between risk reduction, costs and "environmental merit", i.e. the environmental consequences of the risk management action(s) itself. The use of time in source management is a key consideration. Risk management may take some time to achieve permanent effects. Over this time period the functionality of the site may be limited, and of course risks persist. *In situ* techniques for source removal do not guarantee complete elimination of the source, and in the saturated zone even small residual amounts of source materials may cause unacceptable risks to remain. Hence the risk management paradigm, combined with effective site monitoring, is vital to effective remedial decision making for land contaminated by organic pollutants.

While source removal should always be considered, this is not always feasible, nor completely achievable. This difficulty is exacerbated by the limitations of current approaches to characterise sources. Therefore it is important that source management plans for organic contamination are capable of being revisited, and if necessary modified, in the light of new monitoring data, changes in site use or new developments. Key information for source management decision making includes:

- Plume stability / down stream concentrations of contaminants;
- Evidence of potential for removal of contamination by interventions and/or natural processes (for example evidence of contaminant biodegradation in the plume);
- The disposition of receptors and pathways;
- Conceptual models;
- Validation of conceptual models;
- Potential for emissions from interventions and/or natural processes.

The syndicate group agreed with Mr Dries' view that the likely need for long periods of care raises important issues for institutions and requires stable management systems able to operate over extended periods.

Plenary Discussion

The key conclusion of this workshop is:
Risk based decision making is the best available paradigm for dealing with the problems posed by land contamination. Its advantages are that it is systematic and objective, and it provides a consistent and defensible basis for considering uncertainties, discussing options and making decisions. However, a number of challenges face practitioners of users of risk assessment and risk management, in particular: public acceptability; dealing with issues of uncertainty; validation and the development of practical robust and agreed tools.

However, while risk based decision making is rapidly becoming the industry and regulatory norm, it is not safe to assume that it will be acceptable to all stakeholders in the decision making process. In some cases it may be because stakeholders do not understand risk based decision making, but it is equally possible that they reject it and have different values and priorities. It does seem that greater effort needs to be made to demonstrate the value of the risk based approach.

Significant uncertainties exist in the tools available for risk assessment, from the sampling and analysis for source characterisation, through to the data sets and models used for developing a risk prognosis. The principle causes of uncertainty are largely related to the complexity and heterogeneity of the ground environment, issues of bioavailability and the suitability of source data, such as toxicological information. These ought to determine the risk assessment research agenda. A large element of conservatism has been built into existing risk assessment procedures to provide a "safety net" against these uncertainties. It is important that the degree of conservatism is adequate to provide protection, but not so great as to cause the misuse of valuable resources on excessive remediation, when none was in reality necessary. Indeed remediation itself is not without an environmental impact, as discussed below.

Several delegates spoke about the need for a better system of validation of risk assessment tools, and the comparative project initiated by CLARINET and NICOLE is noteworthy as a first step in this process. A further suggestion made (by Paolo Cortesi, the Chairman of NICOLE) was for NICOLE and CLARINET to collaborate to provide a compendium of risk assessment case studies as a public record of the state of the art.3

3 The recent Framework 5 Research Workshop in Venice has agreed with the need to establish a compendium of risk assessment / management case studies in Europe. DG Research workshop on The Protection Of European Water Resources - Contaminated Sites, Landfills, Sediments, held in Venice, 21-23 June, 2000.

However, the abundance of risk assessment publications is in itself a problem for many practitioners and users. Hundreds of R&D projects are taking place around the world, with hundreds of publications. This poses a problem of information overload to the "humble" practitioner, who can find it hard to see how new information fits with practical circumstances. There is perhaps a need for a European "centre of excellence", perhaps network based, able to distil the best available risk assessment and management information into practical tools, and at the same time ensure that future research is matched to real needs.

Some concern was expressed about the level of conservatism built into risk assessment methods. Given the limitations of the tools currently available, this precautionary approach is no doubt appropriate. However, the inability of risk assessment methodologies to consider the likely availability and accessibility of contaminants to pathways, particularly post-treatment, was felt by many to be unduly restrictive on risk management. "Over-engineered" solutions may not only increase the environmental burden of the remediation process itself, but are also an unnecessary use of resources.

A further challenge was felt to be the development of a higher quality of technical skills in the service provider community. While many service providers offer a high quality and reliable risk management consultancy, various anecdotes of poorer projects were exchanged, for example where early mistakes resulted in much more expensive remedies. In part the solution is in the hands of the site owners in ensuring firstly that they seek technical excellence, and secondly that they adequately resource and reward it. Lowest cost does not usually mean best value. However, another part of the solution might be including a strong training and education element in the "centre of excellence" network suggested earlier. The first building blocks of this network might be NICOLE, CLARINET and a new network of researchers and academics being initiated by the University of Tuebingen.

The workshop discussions also showed a general consensus amongst the different stakeholder groups who took part (industry, service providers, business, regulators and researchers) that sustainable development was at least an important decision making principle as risk management. Sustainable development seeks to ensure that the resource, economic, environmental and social consequences of a particular activity are not detrimental to our general well being and the ability of future generations to meet their own needs. This interest in sustainable development as a decision making principle is emerging simultaneously from all of the major stakeholder groups involved in contaminated land. There is an urgent need to develop appropriate decision making tools, integrated with risk management. A prerequisite to this development is the collection of substantive information on what actually constitutes the sustainable development fundamentals for contaminated land management. These broader considerations might help the contaminated land community better address and defend decisions on issues such as:

- The value of groundwater remediation projects over extensively contaminated aquifers;
- The appropriate balance between control of individual site remediation projects and the encouragement of brownfields redevelopment as opposed to the use of greenfield sites.

Harald Kasamas (of CLARINET) pointed out the need to consider decision making not just at the level of individual sites, but in the context of regional and spatial planning needs. The planning community have a similar stake in contaminated land decision making as much as regulators, as both act on behalf of the public interest.

Related to sustainable development considerations is the recognition by all parties that some contaminated land problems are intractable and likely to take long periods for their resolution. This poses issues about the long term stability of organisations committed to a long term activity such as an MNA (be it a company or a regulator) and the suitability of current administrative and bureaucratic procedures for recording decisions and information over long periods of time. This might constitute and important area of research for contaminated land management in its own right.

An interesting suggestion was that it would be useful for NICOLE and CLARINET to stimulate the development of training packages concerned with risk communication and negotiation, in particular:

- To help authorities to be more effective in their dealings with problem holders, and
- To help all professional stakeholders better communicate with the public at large.

Recommendations

Risk management and sustainable development are the two key decision making criteria for contaminated land management, and should be explicitly considered in all remediation decision making for source management. Early and effective communication with all legitimate stakeholders is recommended to ensure the earliest and widest acceptability of any decisions reached.

Four important areas for further research and development in the field of contaminated land management have been identified:

- The improvement and validation of risk assessment methods and the harmonisation of key data sets used by these methods;
- The continuing enhancement of source control and pathway interruption as risk management tools, particularly for the saturated zone;
- The integration of sustainable development considerations into contaminated land decision making at a site specific and regional basis;
- The development of effective administrative procedures and systems for the recording and management of information and decisions over long term risk management projects.

There is some concern about the uneven spread of knowledge amongst service providers and problem-holders, and indeed those proposing research and development. The development of a knowledge network / virtual centre of excellence for contaminated land management information, able to disseminate this information widely emerged as a recommendation on several occasions. The workshop also recommended that CLARINET and NICOLE collaborate to provide a compendium of risk management case studies, with case studies revisited to evaluate the effectiveness of the risk assessment / management activities undertaken.

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