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A review of the Contaminated Land Rehabilitation Network for Environmental Technologies in Europe (CLARINET). Part 2: Working Group findings

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Abstract
CLARINET, the Contaminated Land Rehabilitation Network for Environmental Technologies in Europe was a Concerted Action of the European Commission's Environment and Climate Research and Development Programme. The project ran from 1998 to 2002. Its primary objectives were to develop technical recommendations for sound decision making on the rehabilitation of contaminated sites in Europe and to identify research and development needs, in particular in relation to the EC Fifth Framework Programme (FW5).

CLARINET's findings represent a consensus between experts from 16 European countries and present a philosophical framework for contaminated land management, Risk Based Land Management*, and a series of findings related to the specific interests of its seven working groups. These were: brownfields and redevelopment of urban areas; decision support; groundwater and surface water protection; research programmes and collaboration in Europe; ecological requirements for land reuse; human health effects; and remediation technologies.*

Key words: brownfields, CLARINET, contaminated land risk assessment, remediation, risk management

INTRODUCTION

CLARINET, the Contaminated Land Rehabilitation Network for Environmental Technologies in Europe was a Concerted Action of the European Commission's Environment and Climate Research and Development Programme. The project ran from 1998 to 2002. Its primary objectives were to develop technical recommendations for sound decision making on the rehabilitation of contaminated sites in Europe and to identify research and development needs, in particular in relation to the recent EC Fifth Framework Programme (FW5). The Austrian Federal Environment Agency has published a series of CLARINET reports as hard copy, on CD ROM and on **www.clarinet.at**. This report series includes an *Overview Report*, and more detailed reports from a number of its working groups.

CLARINET's findings represent a consensus between experts from 16 European countries[1] and present both a philosophical framework for contaminated land management now, and in the future, *Risk Based Land Management*, and a series of findings related to the specific interests of its seven working groups (WG). These were:

WG 1 Brownfields and redevelopment of urban areas;*
WG 2 Decision support;*
WG 3 Groundwater and surface water protection;*
WG 4 Research programmes and collaboration in Europe;*
WG 5 Ecological requirements for land reuse;

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This paper has been abstracted form the work of many people in CLARINET

1. Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom

WG 6 Human health effects;
WG 7 Remediation technologies.*
* Report available for download from www.clarinet.at

This paper outlines the findings of these working groups. Each group followed a programme agreed by its members, which differed to some degree from group to group. However, these findings were integrated in the overall report, *Risk Based Land Management* (RBLM), which is summarised on pages 31– 36.[2]

WG 1. BROWNFIELDS AND REDEVELOPMENT OF URBAN AREAS

At present in Europe the term 'brownfield' is used in different contexts and means slightly different things. In some countries, the complexity and context of this term is not recognised. However, all countries in Europe face a significant problem from land used in the past in a way which has left the land not fully suitable for new uses. CLARINET therefore established a working definition of the term brownfield to assist in identifying and comparing issues in different countries. Brownfield sites:

- have been affected by the former uses of the site and surrounding land;
- are derelict or underused;
- have real or perceived contamination problems;
- are mainly in developed urban areas;
- require intervention to bring them back to beneficial use.

WG1 carried out a review of national approaches to the redevelopment of brownfields across CLARINET countries, considering:

- future use;
- site preparation;
- economic viability;
- legal framework.

The review found that:

- contamination is a technical barrier in site preparation;
- the real and perceived future risks from contamination inhibit reuse of the land;
- developers face complex legal requirements in dealing with contamination;
- the cost of dealing with contamination can inhibit redevelopment.

Whilst the presence of contamination can be a serious obstacle in the complex process of redevelopment, brownfield sites also have other, wider problems, many of which are related to the factors that caused the land to become unused, underused or only partially used. These include: the economic factors that caused the decline or cessation of the former use of the land, social problems which have resulted from this economic decline, and the environmental impacts of underused (and possibly contaminated) land.

These problems are not entirely new. Many countries have already introduced policies and programmes aimed at regenerating areas of industrial decline and reusing brownfields. The benefits of reusing brownfields are increasingly recognised for providing urban, economic and social revitalisation, restoring the environment and contributing to a reduction in the consumption of 'greenfield' land.

The lack of a common definition underlying the data obtained from different countries makes it difficult to quantify the scale of the brownfield problem in Europe. However, there are some general indications of the nature and extent of the problem. Three main categories of brownfield can be identified:

- brownfields in traditional industrial areas which have declined (especially in the coal, steel and textile areas, but nowadays also in the chemicals and power sector);
- brownfields in metropolitan areas (which include infrastructure such as railways and docks and some of the 19th century smaller industrial uses);
- brownfields in rural areas (mainly associated with agriculture, forestry, mining or military activities).

In almost all countries there are large-scale regional problems, such as those in the Ruhr area, in Catalonia and in South Wales, as well as urban problems, in particular in cities of rapid growth, such as Helsinki and Dublin, and rural problems, such as those in Lavrion/ Attika. The candidate countries for the European Union are also affected, in some cases to a greater extent.

The creation of brownfields continues through the closure of industrial facilities not regulated under current legislation and without any restoration obligations. Furthermore, some newer industries or uses of land (created on former brownfields) have not been successful, leading to a return of the land to a derelict or underused state. (NB These do not necessarily result in a return to the levels of contamination or dereliction exisiting before development, as some reclamation/remediation would have taken place.)

2. The CLARINET report on RBLM is available for download on www.clarinet.at; also available are the P*roceedings of the Final CLARINET Conference* (June 2001)

Another dimension of the problem relates to the value of the land. Where brownfield land has a high potential value for reuse, minimum treatment for the intended reuse might have taken place – for example to keep project timescales short. Thus not all contamination issues for other types of use might have been addressed. Where the land has very limited economic value, the land may be abandoned forever, as there is no incentive for remediation. These scenarios are common across Europe.

A variety of environmental and land use related legislation may be used to control brownfield redevelopment. Typically this can include:

Environmental control	Development control
Soil quality requirements	Spatial planning policies
Contaminated site controls	Urban design requirements
Water legislation	Building codes
Waste legislation	Mining codes
Emissions (or pollution) control	

At present, there are differences in the policies published for brownfield reuse in different countries. This partly reflects the differences in extent (or perception) of the problem and also the different legal and administrative structures for action. It also reflects a real difference in the drivers for brownfield reuse. In cases where the real need is to stimulate economic growth in disadvantaged areas, or to find land for housing or other uses, the reuse of brownfield is encouraged. Where land is cheap, and the cost of treating brownfields is high, the economy cannot always afford reuse. Whether or not there are different policy approaches, there is a common problem in the integration of spatial planning and environmental considerations within the economic framework of each country. Spatial planners must concentrate on balancing a wide range of factors in relation to land use. If contamination is one of the factors, but is very complex, it is difficult for spatial planners to identify all the possible impacts of the contamination and to decide how best to deal with the issue.

To the investor in brownfield sites the problem is simple and common to all countries – what are the incentives and what are the obstacles to economically viable development?

WG 2. DECISION SUPPORT

Decision support exists to help those who have to take decisions deal with the complex and wide-ranging information involved in contaminated land management. Decision support can be defined as 'the assistance for, and substantiation and corroboration of, an act or result of deciding'. Typically the decision required will be the determination of a best approach for particular action to take place in a particular set of circumstances. WG2 surveyed decision support issues across the 16 CLARINET countries.

Decision support can be provided as written guidance (flow sheets, model procedures) and/or software. It aims not only to facilitate decision making but to help ensure that the process is transparent, documented, reproducible and hopefully robust, providing a coherent framework to explore the options available. The need for decision support is widely recognised, and in recent years a large number of decision support tools (DSTs) have been developed, with varying degrees of success in practical use. These are used to identify the range of options for solutions that best fit the constraints of the problem that they are addressing.

Finding sustainable technical solutions for contaminated land problems is dependent on a range of parallel considerations. Key factors in decision making are the reasons for the remediation work and any constraints

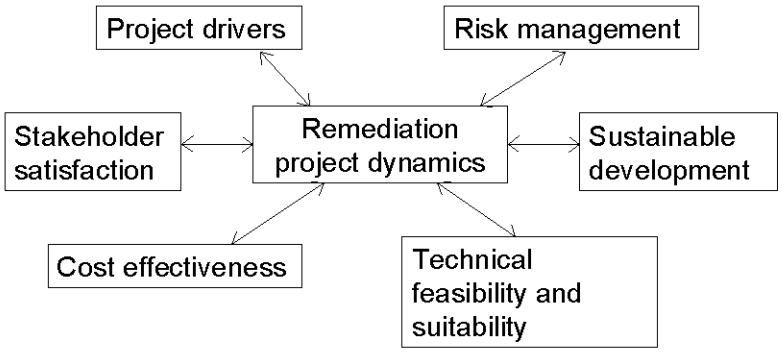

Figure 1. General principles for remedy selection

on it, risk management effectiveness, technical suitability and feasibility, stakeholders' views, cost/benefit ratio and wider environmental, social and economic impacts (i.e. sustainable development), which need to be considered in an integrated and holistic way. A case study is provided in another CLARINET paper (Bardos *et al.* 2002).

Decision support codifies specialist expertise in a way that allows its reproducible use by many. It integrates specific information about a site and general information such as legislation, guidelines and know-how, to produce decision-making knowledge in a way that is transparent, consistent and reproducible. Decision support tools (DSTs) can be distinguished by their:

1. *Functional application.* The functional application to contaminated land management depends on whether the decision support is for risk management, remediation, monitoring and aftercare, sustainable development, etc. This deals with the issues that must be addressed to support the overarching decision. In practice, a number of DSTs address multiple decision criteria.
2. *Analyses used.* Several different techniques can be employed to assist environmental decision-making. In practice, many decision support tools use several of these techniques, or mixtures of different parts of them. For example, software tools might combine risk assessment and cost–benefit analysis techniques to generate risk maps, cost comparisons between remedial options and other decision information, such as optimal risk solutions.
3. *Decision-making role.* The decision-making role describes the type of decision-making being supported, e.g. for managing a single site, or for prioritising a number of sites. This deals with the overarching decision being made at the site.
4. *Nature of the product.* Whether the tool is written guidance, a 'map' of some sort, a series of procedures or a software based system.

The analytical tools used in DSTs, such as multicriteria analysis (MCA), are reviewed in greater detail in the WG2 Final Report, and a number of DST case studies are presented. These include:

- examples of DSTs using Risk Assessment (Spatial Analysis and Decision Assistance, USA);
- examples of DSTs using MCA/MAT (Conceptual Framework for Wider Environmental Value, UK; Decision Aid for Remediation Technology Selection, Italy/UN);
- examples of DSTs using cost–benefit or cost-effectiveness analyses (The WILMA System for Cost Benefit Analysis/multi-criteria Analyses for a Remediation Project, Germany; Land Value Balance, Germany; Methodology for Assessing the Full Costs and Benefits of Groundwater Remediation, UK; Cost Benefit Analysis for Remediation of Land Contamination, UK; Environmental Visualization System Pro, USA);
- examples of DSTs using life cycle assessment (Environmental and Economical Evaluation and the Optimising of Contaminated Sites Remediation, Denmark/Norway; REC System, the Netherlands; Environmental Balancing of Soil Remediation Measures, Germany);
- other examples (The 'Model Procedures', UK; SitePro™, USA; ArcView® GIS, USA; SamplingFX, USA; GroundwaterFX, USA; RBCA, USA)

A variety of techniques have been applied in commercial DST products, and yet others are under development. DSTs are now widely used in contaminated land management for a number of decision-making applications. The most successful software-based tools tend to be fairly specific, focusing on providing support for niche decision-making, for example determining sampling strategy. Applications of techniques using MCA, CBA are widespread as written guidance, but have not found wide acceptance in software applications.

More general tools, for example for remedy selection, are less well developed and accepted, either in software or written guidance, although, again, written guidance tends to have a wider acceptance than software systems.

There is something of a lack of trust in many decision support tools, particularly if they are software-based. This is often related to their lack of transparency, in particular the methods and assumptions involved. There have also been relatively few studies carried out benchmarking different techniques against each other, or testing their ability to support effective and reproducible decision-making in practical land management circumstances.

Furthermore, while a risk management approach is broadly accepted by technical specialists and contaminated land professionals as the most appropriate decision-making basis for contaminated land management, this acceptance is not universal among all stakeholders, particularly 'lay' consultees.

Two major, and as yet unachieved goals, for decision support are to be able to:

- consider sustainable development and risk management in a mutual and holistic way; and
- support stakeholder engagement in a way that is robust and transparent, even to lay audiences.

These goals create a tough challenge, because any decision support must not hamper efficient and cost-effective decision-making or cause excessive delay. A major concern of site owners is that, by widening their considerations and their consultees, they run the risk of stalling the decision-making process; or making it so difficult that, for instance, brownfield remediation becomes less attractive.

WG 3. GROUNDWATER AND SURFACE WATER PROTECTION

All countries are facing significant contamination of these resources by contaminated land which originates from former industrial activities and improper waste disposal. Groundwater is particularly vulnerable. As well as being the main source of drinking water in most European countries, groundwater is also a vital component of surface waters, and many rivers and other aquatic ecosystems are heavily reliant on groundwater baseflow.

When large bodies of groundwater become polluted, the quality of surface water systems will be seriously affected. Surface waters and groundwater are in principle renewable through natural processes, but the formation and the renewal of groundwater in particular can show very long time lags.

The European Groundwater Directive sets a need to protect all groundwater, even if not considered for current and future uses. Groundwater is also addressed by the European Water Framework Directive[28], which has been issued to prevent further deterioration, and to protect and enhance, the quantity and quality of aquatic ecosystems. As a key element of this Directive, improvements in *ecological* quality of surface waters are to be achieved through a staged and iterative process of river basin management planning, encompassing:

- characterisation of river basins;
- analysis of pressures;
- environmental monitoring;
- drawing up river basin management plans, which are statutory and require public participation; and
- implementation of a programme of measures.

This Directive may provide an additional legislative driver for the remediation of contaminated land. The achievement of good status by all waters within 15 years, in particular the good ecological status of rivers, will also encourage the management of point source and diffuse contamination and other environmental sources of pollution, such as contaminated sediments.

Contaminated land has been usually considered in two separate contexts: human and/or ecosystem health and water pollution. The former has often been seen as the most important political driver for clean-up on a local scale, but the Water Framework Directive will be an important legislative driver common to all European countries in the future.

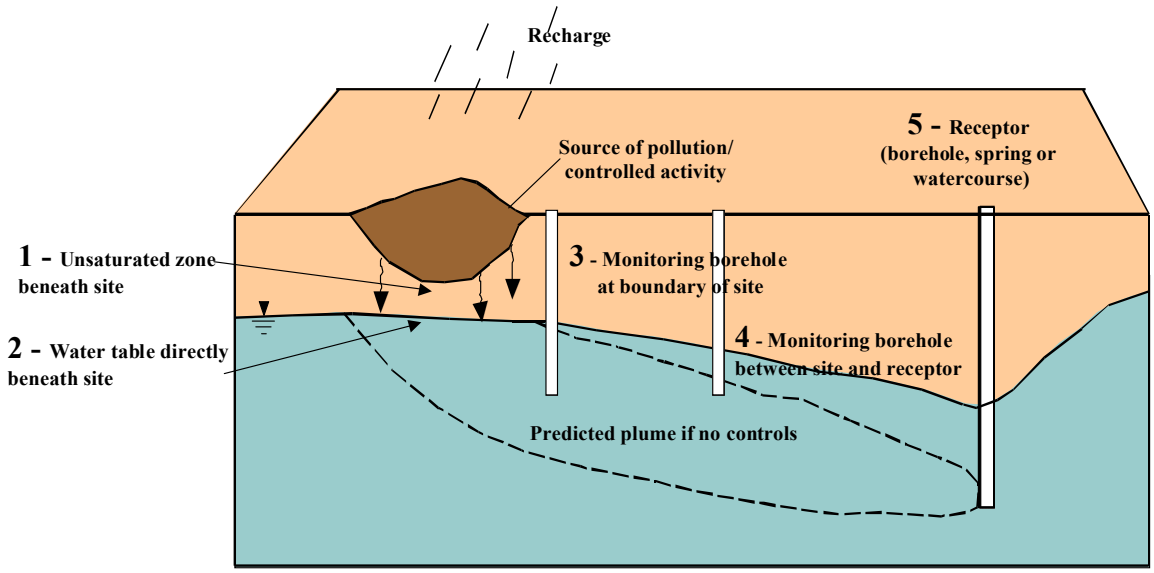

Figure 2. Points of compliance

WG3 carried out a survey of all CLARINET participants, representing most of the EU Member States, to establish a common understanding of different countries' approaches and underlying differences in relation to water resources management, groundwater protection and remediation, and to identify important issues at a European level. Its main findings are as follows.

The principles that underlie the risk assessment approach to water resources in Europe are:

- definition of the sustainability of the resources;
- prevention of new pollution;
- understanding of the primary role of groundwater (as a drinking water resource and/or providing baseflow to rivers or wetlands, but also as a specific ecosystem to be protected for its own sake);
- remediation of past pollution where this is necessary to protect the aquatic environment, terrestrial ecosystems and water users.

There are differing perspectives across Europe about the importance of groundwater as a source of drinking water. This is because the reliance on groundwater for drinking water supply is highly variable on a regional scale both within Europe and within individual countries and is clearly related to the geographical distribution of aquifers. Also there are cultural differences. Some countries will accept remediation by treating groundwater before supply whilst others will not.

The points of compliance used in regulations for both protection ('new' pollution) and remediation ('old' pollution) of water resources are differently defined in the European countries due to differences in national regulations or differences in the interpretation of EU regulations, as illustrated in Figure 2.

The Groundwater Directive and the Water Framework Directive are highly precautionary in their approach to preventing new pollution. The point of compliance for List I substances is therefore the top of the water table. This applies to *all* groundwater regardless of use. However, for historical pollution a more risk-based approach may be taken which may take account of the use of the groundwater, the feasibility of cleaning it and the pathway influences (e.g. natural attenuation).

In many cases, it will not be possible to deal immediately with all groundwater pollution from contaminated land, and long-term care is likely to be a key feature of the interface between contaminated land and groundwater. This may require long-term control over a considerable land area. Hence land use planning controls will have an important part to play in applying this approach.

Important issues for further investigation included the following:

- fundamental science to develop better solutions – in particular knowledge about natural processes, interactions between contamination and the effect of hydrogeological and biogeochemical factors;
- acceptable levels of residual pollution need to be set for environmental protection;
- to consider monitored natural attenuation (MNA) as an acceptable option in the 'appropriate' circumstances, the timescale could be an important limit (30 or 50 years may be necessary to achieve the remediation goal). Questions about liabilities in the long term, particularly if the approach fails, need to be addressed;
- dealing on a wider scale with cumulative risks – such as those which occur in urban areas – or with integrated implementation of solutions should be considered.

WG 4. RESEARCH PROGRAMMES AND COLLABORATION IN EUROPE

WG4 included national research programme managers from eleven European countries and DG Research from the EU. It carried out a survey of national and EU research programmes related to sustainable land and groundwater management issues. The key findings of this survey are as follows:

- the budgets of national RTD programmes in Europe add up to a total of about m20m/year with about _10m from the EU budget (2001). Altogether, there are about m30m/year available for contaminated land and groundwater research across Europe. The annual investment in RTD for sustainable land management is only about 0.03% of the total cost of the problem. The research programmes identified are listed in Annex 2;
- before WG4, there was no co-ordination whatsoever between national RTD programmes in Europe for this sector. The consequence is that all countries go through similar learning curves, resulting in a considerable overlap of research projects and targets;
- eligibility for national RTD programmes is usually restricted to countries' own national research community. This means that cross-fertilisation and knowledge exchange among countries using focused partnership projects has been limited;
- dissemination of project findings through national RTD programmes was felt to be rather modest. Opportunities provided by the Internet are not well used;

- there is no co-ordinated approach to focusing the various RTD programmes in Europe towards the major gaps in scientific knowledge.

WG4's overall conclusion was that enhanced co-ordination between countries' national research approaches would considerably increase the effects and yields of the resources invested in RTD, and facilitate the development of a *European Research Area* for this sector. WG 4 recommended taking steps towards establishing a co-ordinated European research policy for contaminated land and water management:

- providing a platform for research programme managers to exchange information on national research priorities, funding mechanisms and knowledge dissemination;
- striving for a more coherent integration of national and European research activities. This could be achieved through a closer collaboration between various scientific and technological research organisations in Europe;
- taking a joint approach to the need for and means of financing large research projects in Europe. For example, European researchers and technology developers could test and compare their products at specific demonstration sites in Europe;
- networking of existing centres of excellence and competence in Europe and the creation of virtual centres through the use of new interactive communication tools;
- co-ordination of an agenda of joint research priorities and stimulation of trans-national RTD projects and European peer review of programmes;
- stimulation of trans-disciplinary research involving more stakeholders in the projects (a goal of many of the networks summarised below).

WG 5. ECOLOGICAL REQUIREMENTS FOR LAND REUSE

WG5 held a workshop on Ecological Risk Assessment (ERA) in the Netherlands in 2001 to:

- discuss the scientific development and policy needs for site-specific ecological risk assessment;
- identify available tools;
- identify the gaps and needs for future development in this area;
- explore possibilities for a European framework for site-specific risk assessment.

The main findings of this workshop are available on **www.clarinet.at**.

WG5 also surveyed the use of ecological risk assessment and the perceived need for this technique among CLARINET countries. Most countries use or intend to use some kind of ecological reasoning in generic guidelines and/or site-specific assessments, typically based on information on plants, soil fauna, micro-organisms and processes. There are important uncertainties in ERA:

- the reliability of extrapolations of 'lab' findings to the field;
- dealing with heterogeneity in test methods;
- reliability of models;
- varying expert opinions;
- a lack of basic knowledge on soil biota.

A staged approach to ERA is suggested, with increasing levels of sophistication and effort being applied only when the circumstances demand it, as illustrated in Figure 3.

The initial tier of assessment should be a practical, easy to implement step that is relatively inexpensive. Tier 1 should include site history (potential contamination), chemistry (analyses and comparison with soil screening levels) and biology (bioassays optional at Tier 1). An expert view of the site may provide additional information. If potential risks are identified then assessment proceeds to Tier 2.

Tier 2 involves more detailed characterisation of physical/chemical characteristics, ecology and biomonitoring (considering land use and pollutant types). Predictive models may be used. Its aim is to develop site-specific acceptance criteria for use in decision making and discussions with stakeholders. If there is insufficient information available to make a decision then the ERA proceeds to Tier 3.

Tier 3 aims to collect further information to reduce uncertainty, for example, using mesocosm studies, detailed field studies, advanced modelling and field validation of laboratory measurements and models.

The information collected through the ERA should be incorporated into a site conceptual model.[3]

While the development of a common European framework for ERA is seen as a useful step by WG 5, it is important that any such framework is flexible, so that country-specific details can be built in. The approach should be tiered, decision-oriented and simple. The development of bioassays and interpretation of its

3. The site conceptual model (SCM), is a vital component in risk management decision making, as it sets out the critical pollutant linkages of concern for a particular land contamination problem (Nathanail, C.P., Nathanail, J., McCaffrey, C. *Scottish Executive Technical Guide To Part IIa Implementation: Assessment of Potentially Contaminated Land*. Scottish Executive, Edinburgh (in press))

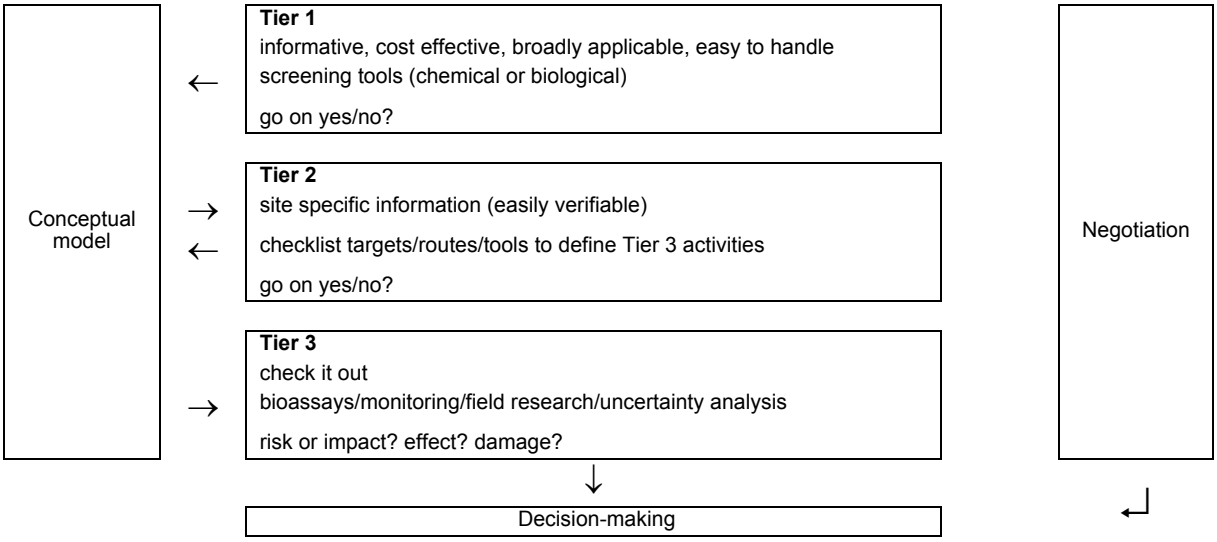

Figure 3. Suggested staged approach to ecological risk assessment

results can also be taken up by networks/organisations such as ISO.

WG 6. HUMAN HEALTH EFFECTS

WG 6 produced three main outputs:

1. an international comparison of human exposure model variability;[4]
2. a workshop (2001) exploring the potential contribution of environmental epidemiology to contaminated land risk assessment;[5]
3. BioAvailability Research Group Europe (BARGE).

International comparison of human exposure model variability

The calculation of human exposure to contaminants can lead to a wide range of results, depending upon the model, parameters selected and model user. The consequences can be far-reaching. Model calculations using different models from seven different European countries were compared (model given in brackets):

- ANPA, Italy (ROME);
- DHI Water and Environment, Denmark (CETOX-human);
- INERIS, France (no name);
- Kemakta Konsult AB, Sweden (no name);
- LQM/ University of Nottingham, UK (CLEA);
- RIVM, the Netherlands (CSOIL);
- VITO, Flanders, Belgium (VlierHumaan).

Comparisons were based on the same scenarios, with differences in soil use, soil type and contaminant used in the comparisons. Twenty hypothetical scenarios were used. These scenarios differed in the following ways: two land uses (residential and industrial), two soil types (sandy soil and clay soil), and five different contaminants. The contaminants (benzo(a)pyrene, cadmium, atrazine, benzene, and trichloroethene) are of different types and are considered to be common throughout Europe, and have different exposure characteristics.

Results of these comparisons indicate that calculated exposures can vary substantially. This variation is larger for more volatile contaminants, and to a lesser extent, for contaminants that are more mobile, or available for plant uptake. This is partly the result of the use of different exposure factors, but more significantly due to the different mathematical formulae used to compute the distribution over the different soil phases and the transfer of contaminants along different pathways. The study found that the use of standardised or 'own' input parameters had no clear influence on the variation in exposure. There is also no clear difference between the variation in calculated exposures for residential versus industrial sites, or for sandy soil versus clay soil. The impact of choice of model and type of

4. Swartjes, F.A. (in press) *Variation in Calculated Human Exposure: Comparison of Calculations with Seven European Human Exposure Models.* RIVM report 711701030. RIVM, Bilthoven, the Netherlands

5. Environment Agency and CLARINET (2001) *Epidemiology Workshop on Human Health Tools and Techniques. Report of a joint workshop*, Coventry 14–15 March, 2001, ISBN 1-85-705592-6, Ref. HO 06/01-300-A, Environment Agency, Bristol, 33 pp.

contaminant on variation in calculated exposure is much more evident. Possibly differences in model performance can be attributed to 'misunderstandings', i.e. differences in interpretation in definitions of outputs and scenarios.

Environmental epidemiology workshop

A workshop was held in Coventry on 14 and 15 March 2001. With the combined objectives of the Environment Agency, CLARINET and its Working Group 6 in mind, the workshop was designed as an awareness-raising event for practitioners. It included technical overviews from expert practitioners in environmental epidemiology and case study material from Environment Agency experience and areas of interest to CLARINET. The principal conclusions of the workshop were as follows.

Epidemiology is a specialist tool. Prior to embarking on an extensive epidemiology study, it is essential to collate all information available in the study area, and potential exposure pathways should be clearly established. The actual problem must be clearly defined to ensure that there is a common understanding of the issue being investigated.

The first step is to carry out a focused exposure assessment. It is important to determine at an early stage what data sources are readily available. If little or no monitoring has been undertaken, what is the minimum data set required? What data can be modelled? And what are the minimum data requirements for good quality epidemiological studies? The aim is to characterise the site(s) and population(s) of concern, identifying exposure pathways from the site to the population of interest. It should consider environmental monitoring (e.g. concentrations of contaminants, emissions, etc.) and modelling (e.g. air dispersion or groundwater modelling). The exposure assessment should identify the critical risk aspects by establishing a source – pathway – receptor linkage. Only when a complete exposure pathway linkage has been established should an epidemiology study be considered. The identification of the critical risk aspects will allow for the design of a more targeted epidemiology study.

Detection of low risk excesses is highly dependent of good and accurate exposure assessment. Thus, although accurate exposure data are desirable in any epidemiological study, such data are even more important in environmental epidemiology. Therefore, close collaboration between environmental epidemiologists and other experts with good knowledge of the exposure data is essential.

However, many epidemiological studies will not have enough resolution to highlight the cause of a statistical significance between the exposed and control populations. Detection and attribution of chronic health effects with exposure are rarely achieved.

BioAvailability Research Group Europe (BARGE)

Ingestion of soil is a dominant exposure route for humans. After soil ingestion, contaminants can be partially or totally released from the soil matrix during digestion. The fraction of the contaminant that is mobilized from soil into the digestive juice (chyme) is defined as the bioaccessible fraction. This fraction is considered to represent the maximum amount of contaminant available for intestinal absorption.

In risk assessments it is currently assumed that the oral bioavailability of contaminants ingested with soil is the same as with food or aqueous solution. However, it is widely believed that this yields an overestimation of the risk. In the absence of more detailed information, the default value used for relative oral bioavailability is commonly 100%. This default value is used in most guideline values (trigger values, intervention values, soil screening levels, etc.). A more realistic value and approach could have important economic consequences, and may lead to more transparent decision making in areas with high natural background levels of potentially harmful substances. Better assessment of oral bioavailability is especially important for contaminants like lead, arsenic and polyaromatic hydrocarbons.

BARGE was set up in December 1999 for co-operation and exchange of data on oral bioavailability of soil contaminants. Participants agreed to compare the five existing *in vitro* digestion models (listed in Table 1) by using three identical soil samples, each containing three contaminants (As, Cd and Pb) in a 'round-robin' experimental set-up.

Table 1. Different types of *in vitro* digestion models within the BARGE

Method	Institute	Country	Type of digestion model
SBET	BGS	UK	Static gastric model
DIN	RUB	D	Static gastro-intestinal model
In vitro digestion model	RIVM	NL	Static gastro-intestinal model
SHIME	LabMET /Vito	B	Static gastro-intestinal model
TIM	TNO	NL	Dynamic gastro-intestinal model

A wide range of bioaccessibility values were found for the three soils: As 6–95%, 1–19%, 10–59%; Cd 7–92%, 5–92%, 6–99%; and Pb 4–91%, 1–56%, 3–90%. Bioaccessibility in many cases was less than 50%, indicating that a reduction of bioavailability can have implications for health risk assessment. Although the experimental designs of the different digestion systems

are distinct, the main differences in test results for bioaccessibility can be explained on the basis of the applied simulated 'gastric' pH. High values are typically observed for a simple gastric method, which measures bioaccessibility in the gastric compartment at low pHs of 1.5. Other methods that also apply a low gastric pH, and include intestinal conditions, produce lower bioaccessibility values. The lowest bioaccessibility values are observed for a gastro-intestinal method which employs a high gastric pH of 4.0. Differences in the applied gastric pH in the various *in vitro* digestion models, also correspond to different physiological conditions, i.e. fed and fasted state.

Further information on BARGE and participation in BARGE is available from: **www.schelwald.nl/pages/barge**.

WG 7. REMEDIATION TECHNOLOGIES

Several billion Euros 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. A risk-based decision-making process for remediation is now the norm across most EU Member States (CLARINET and NICOLE 1998). 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 (Ferguson *et al.* 1998; Ferguson and Kasamas 1999).

The WG 7 report carried out a review of implementation of remediation technologies in the different CLARINET countries. The key findings of this study are as follows.

The future use of land, and the money available for developing this use, are powerful controlling influences on the remediation approaches used. There is a constant pressure for lower remediation costs, both to improve the economics of brownfield reuse for 'hard applications' such as housing or commerce; and for 'softer' uses such as for 'green space'. Cost effectiveness is not just a product of reducing remediation costs, but also of finding remediation approaches that provide an additional enhancement to the value of the land.

In many countries, waste management legislation, taxation and regulation has a controlling influence on the economic viability of different remediation approaches, affecting in particular the viability of treatment based techniques.[6]

The importance attached to the protection of groundwater varies between countries, and this seems to be associated with the degree of utilisation of groundwater. For example, in countries like Norway, where only 15% of the groundwater resource is utilised for water supply, remediation is rarely initiated to protect groundwater.

Assuming that a remedial approach can be adequately monitored and controlled, there is an increasing desire to promote *in situ* over *ex situ* solutions and on-site solutions over solutions based on removal off site. However, there are often conflicting pressures affecting whether or not an on-site or off-site approach is taken. In some cases stakeholders may express a preference for a solution based on removing materials off site. This may be related to concerns over residual liabilities, which in turn are related to concerns over the duration, feasibility or completeness of on-site solutions. Offering previously validated solutions and developing an appropriate verification strategy for the sites in question are key steps in dealing with these concerns. Conversely, removal of materials off site may be problematic because of transportation and related problems, or because excavation is not considered technically or economically feasible.

In general, concerns over feasibility tend to be greater for innovative remedial approaches, even if these have long-standing track records in other countries. However, it is often these innovative solutions that are seen to offer more in terms of reducing wider environmental impacts and furthering the cause of sustainable development.

WG 7 attempted to review remediation costs in the different CLARINET countries, but found difficulties in obtaining comparable cost figures for different technologies. Costings are approached differently in different countries, and are in any case dependent on site-specific circumstances. It was noted that generally quoted 'unit' prices, e.g. on a per tonne basis, seemed higher than costs bid for large remediation projects. Costs reported for the same technology varied by orders of magnitude. Costs are also related to the availability of the technologies in some countries, and the size of the remediation market, as well as different views on technology definitions. The tentative cost data collected are as follows:

Predominantly *ex situ* technologies:

- Bioremediation: 20–40 m/t, assuming that:
  - low cost figures refer to composting; and
  - high cost figures refer to bioslurry or reactor treatment systems;
- soil washing 20–200 m/t;
- stabilisation/solidification 80–150 m/t;
- incineration treatment 170–350 m/t;
- thermal treatment 30–100 m/t.

6. Treatment based approaches destroy, remove, or detoxify the contaminants contained in the polluted material (e.g. soil, ground water etc).

In situ technologies:

- 20–60 m/t.
  - depending on technology and application site.

Key areas for future remediation R&D identified by WG 7 included the following:

- collating comparable cost data;
- developing quality assurance and control systems;
- providing opportunities for verifiable field-scale demonstrations of treatment-based remediation, and benchmarking performance;
- development of sustainability appraisal techniques for remedy selection;
- developing an enhanced ability to apply integrated or combined approaches for complex contamination problems;
- developing an integrated approach to the planning, investigation, remediation and aftercare phases of contaminated land management;
- documenting long-term performance of pathway/ exposure control technologies;
- determining endpoints for remediation related to soil functionality.

ON-GOING AND FUTURE INITIATIVES

Although CLARINET has now completed its work, a number of international networks continue to support research and development and best practice in contaminated land and groundwater management.

The Ad Hoc Working Group on Contaminated Land

The Ad Hoc Group is an informal coalition of professionals from regulatory agencies and government departments with responsibilities for contaminated land management. It has similar functions to the Common Forum (see below), but has a wider geographical coverage (world-wide) and carries out a slightly wider range of functions. It meets every two years and has a secretariat that rotates from country to country. Approximately every two years it surveys contaminated land policy developments across the participating countries. Meetings tend to be only open to government representatives. Further information about the Ad Hoc Group is available on its website: **www.adhocgroup.ch/**

ANCORE

ANCORE, the Academic Network on Contaminated Land Research in Europe (ANCORE) was inaugurated by the Centre for Applied Geoscience at the University of Tübingen. ANCORE includes currently more than 60 research institutes from 16 European countries and covers a broad range of scientific disciplines involved in the field of contaminated land and groundwater research. Further information is available from www.ancore.org

CABERNET

The Concerted Action on Brownfield and Economic Regeneration Network (CABERNET) was established in January 2002. It is a multidisciplinary expert network that aims to facilitate new practical solutions for urban brownfields. Its vision is to: 'Enhance rehabilitation of brownfield sites, within the context of sustainable development of European cities, by the provision of an intellectual framework for co-ordinated research and development of tools'. CABERNET is a three-year initiative, co-ordinated by the University of Nottingham in association with the German Environment Agency (Umweltbundesamt), funded under the EU 5th Framework programme. The network consists of 49

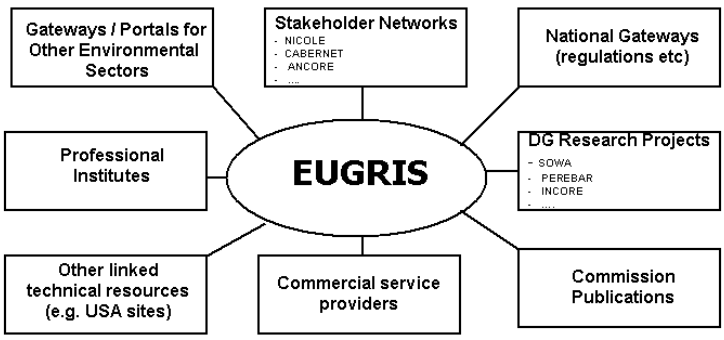

Figure 4. EUGRIS

members and six co-ordination team members originating from 21 countries across Europe. The network is focusing on four key objectives: (i) improving awareness and enhancing understanding across the professional disciplines; (ii) developing a conceptual model for brownfield issues; (iii) identifying research gaps and proposing co-ordinated research activities; and (iv) identifying best practice for practitioners. For further information visit www.cabernet.org.uk

Common Forum

The Common Forum is a platform of co-operation between representatives of the EU Member States, the European Commission and the European Environment Agency on issues related to contaminated land in Europe. Its first meeting took place in Bonn (Germany) in 1994 and since then in Maastricht (1995), Stockholm (1996), Amsterdam (1997), Edinburgh (1998) and Copenhagen (1999). This year, Flanders decided to organise the Common Forum as a side-event of the Belgian Presidency of the EU. The objectives of the Common Forum are to identify thematic areas for EU-wide co-operation, to enhance the dialogue between the different international activities, to collect and discuss the results of these activities and to make recommendations on technical issues and practical aspects to the European Commission and the European Environment Agency and to facilitate the understanding of each EU Member State's approach to tackling the problem of contaminated land. Meetings are only open to government representatives.

EUGRIS

EUGRIS is a 2.5 year Accompanying Measure that aims to develop a web-based and user friendly information platform for soil and groundwater management. EUGRIS will be funded under Key Action 1 of the Fifth Framework Research Programme of the European Commission. This information gateway will be openly available and provide a comprehensive and overarching information resource for sustainable groundwater and land management practice. The co-ordination will be with the Federal Environmental Agency of Germany. The core objective of EUGRIS is the development of a fully functioning 'pilot' version. It will be based on information provided by 'pilot countries' (UK, Denmark, France, Hungary and Germany), information provided by EC projects, Concerted Actions and other international activities and initiatives.

Information from the pilot countries will be provided by the partners of the project. They represent a mixture of experienced regulating and researching governmental organisations, one university and a number of SMEs from the pilot countries. EUGRIS will be designed to cater for a range of users from researchers seeking advanced information on specific topics to general enquiries from those seeking a basic level of easy-to-digest information. EUGRIS will furnish an easy route of access to knowledge about contaminated land and groundwater issues for all stakeholders, and so improve the general efficiency of information use in a wider Europe. EUGRIS will further assist those synthesising and integrating the results of successful past and ongoing RTD projects and their implementation into policy approaches across Europe, as well as servicing future and current RTD. EUGRIS is expected to start at the end of 2002. A web link will be available from February 2003 on www.contaminatedland.info

Image-Train

Image-Train is an Accompanying Measure supporting cost-effective and eco-efficient remediation techniques for groundwater resources in Europe. It is a cluster of three current FP5 projects (INCORE, PIRAMID and PEREBAR) and focuses in particular on training young scientists. It integrates the results and innovation delivered by EC funded research projects, specifically those concerning passive *in situ* techniques for groundwater remediation approaches. One major focus of this project is dedicated to efficient knowledge and information transfer towards the European scientific community and potential end-users, and includes also a particular emphasis on the specific situation in EU Accession Countries. Among its meetings will be three Advanced Study courses for academics and young scientists. Public access to the results and information will be provided via a web page, reports, newsletters and technical/scientific workshops. The main objectives of Image-Train are to combine innovative research projects and available knowledge supplied by EU funded RTD projects and shorten their transfer to practical application for problem solving, and to transfer existing and emerging knowledge to young scientists and academics in the European Union and the EU Accession Countries. All Image-Train products can be directly downloaded from the project's website: www.image-train.net/

NATO/CCMS Pilot Study – Evaluation of Demonstrated and Emerging Technologies for the Treatment and Cleanup of Contaminated Land and Groundwater

This recent pilot study is led by the USA, with Germany and the Netherlands as co-pilot countries. The intent of these meetings is to freely exchange information and experiences among remediation experts from various countries. The goal is for each country to go away from each meeting having increased their knowl-

edge in the remediation field. Since these meetings have started, this goal has been met. Information from the pilot study is placed on NATO (www.nato.int/ccms/home.htm) and EPA (www.clu-in.org/partner1.cfm) websites. Each meeting consists of four parts: (1) a technical session addressing a specific topic; (2) country updates on regulatory and environmental issues; (3) a field trip, and (4) discussion of projects associated with the pilot study. An annual meeting report and technical session report are produced after each meeting. These reports are placed on the above websites. A further phase of the Pilot Study has just been agreed. For more information visit www.natoc.int/ccms

NICOLE

NICOLE (Network for Contaminated Land in Europe) was set up in 1995 as a result of the CEFIC 'SUSTECH' programme which promotes co-operation between industry and academia on the development of sustainable technologies. NICOLE is the principal forum that European business uses to develop and influence the state of the art in contaminated land management in Europe. NICOLE was created to bring together problem holders and researchers throughout Europe who are interested in all aspects of contaminated land. It is open to public and private sector organisations. NICOLE was initiated as a Concerted Action within the European Commission's Environment and Climate RTD Programme in 1996. It has been self-funding since February 1999. NICOLE's overall objectives are to:

- provide a European forum for the dissemination and exchange of knowledge and ideas about contaminated land arising from industrial and commercial activities;
- identify research needs and promote collaborative research that will enable European industry to identify, assess and manage contaminated sites more efficiently and cost-effectively; and
- collaborate with other international networks inside and outside Europe and encompass the views of a wide range of interest groups and stakeholders (for example, land developers, local/regional authorities and the insurance/financial investment community).

NICOLE currently has 160 members. Membership fees are used to support and further the aims of the network, including: technical exchanges, network conferences, special interest meetings, brokerage of research and research contacts and information dissemination via a website, newsletter and journal publications. NICOLE includes an Industry Subgroup (ISG) – with 27 members; a Service Providers Subgroup (SPG) with 32 members; 85 individual members from the academic sector/research community; and 16 members from other organisations, including research planners, non-profit-making organisations, other networks and funding organisations. Some members are involved in both the ISG and the SPG. For further general information, further meeting reports, network information and links to contaminated land related websites, visit NICOLE's website: www.nicole.org

Permeable reactive barrier network

The Permeable Reactive Barrier Network (PRB-Net) held its first workshop during 25–27 April 2001, focusing on PRB technology and its current international status. This workshop included a field trip to two reactive barrier sites in Northern Ireland: a zero valent iron reactor and a biological PRB (both firsts in Europe). The workshop attracted delegates from 13 different countries, including the USA, Canada, Germany, Belgium, France, the Netherlands, and Korea. A number of other workshops and an international conference on reactive barriers/zones are planned for the next two and a half years, serving to disseminate information to the wider community and facilitate communication between inter-disciplinary groups. Further details can be found at www.prb-net.org

REC

The Regional Environmental Centre for Central and Eastern Europe (REC) is an international, diplomatic status organisation with a mission to assist sustainable development and coping with environmental challenges in Central and Eastern Europe (CEE). The REC fulfils its mission through encouraging cooperation among governments and businesses and NGOs, supporting the information exchange and promoting cross-sectoral (or multi-stakeholder participation and dialogue in environmental planning and decision making. The REC was established by the governments of Hungary and the USA, and the European Commission in 1990, and it is legally based on a charter signed by 28 countries so far. The REC's main donors include the European Commission, the governments of the USA, Japan, Canada, the Netherlands, the UK, Denmark, Austria, Germany, Hungary, Czech Republic, Slovakia, Croatia, as well as other intergovernmental and private institutions. For further information view www.rec.org

RESCUE

RESCUE (Regeneration of European Sites in Cities and Urban Environments) is a research project in the framework of key action IV 'Cities of tomorrow and cultural heritage' within the 5th Framework Programme of the European Community. Started in March 2002, RESCUE is a 36-month research project integrating the concept of sustainability into brownfield

regeneration. Based on the analysis and evaluation of current practice in industrial regions in France (Nord-Pas de Calais), the UK (Derbyshire, North-East England), Poland (Silesia) and Germany (Ruhr, Southern District of Leipzig), RESCUE distils best practice approaches at reduced costs and integrates its results into a holistic approach involving new methodologies, procedures and instruments for a sustainable regeneration of European industrial brownfield sites. The regeneration process will be broken down into the main steps of decision making and analysed along transnational work packages by interdisciplinary teams. For further information visit **www.rescue-europe.com**

SedNet

The SedNet mission is to be a European network for environmentally, socially and economically viable practices of sediment management on river basin scales. Due to their trans-boundary nature, no single water manager or country has the responsibility for solving sediment management problems at such scale. SedNet has been established to help to structure and facilitate a European approach on this issue. SedNet is funded for three years as a Thematic Network project by the EU under FP5 (Contract No. EVK1-CT-2001-20002, starting date: 1 January 2002). Its inaugural conference was held at 22 and 23 April 2002 at the SedNet home base at San Servolo Island, Venice, Italy. More than 120 sediment experts from 18 countries visited the conference. For further information visit **www.SedNet.org**

SENSPOL

The EC Environment and Sustainable Development Programme's network SENSPOL focuses on 'Sensors for monitoring water pollution from contaminated land, landfills and sediment'. SENSPOL provides a route to identify environmental monitoring requirements and proposed solutions. For further information visit **www.cranfield.ac.uk/biotech/senspol.htm**

CLARINET FINDINGS AND THE UK

The UK made a major contribution through DEFRA, and its contractors, and the Environment Agency to CLARINET, with further voluntary involvement from 15 individual experts. UK expertise has both influenced, and been influenced, by participation in CLARINET. The major assets from CLARINET have been the written reports (available from **www.clarinet.at**), a number of further networking initiatives and projects, but most important of all a developing European consensus on the use of risk management and sustainable development as decision-making disciplines for contaminated land and groundwater. CLARINET's outputs have been made widely available via the Internet and technical journals, as well as at an open conference in 2001 in Vienna. An open meeting on CLARINET was held in Nottingham in March 2002.

Information from CLARINET was highly regarded by those surveyed in the recent DEFRA audit of contaminated land research.[4] However, there are also some lessons that can be learnt for future UK involvement in contaminated land networks.

Accessibility of information, and the openness of CLARINET to participation, have been seen as limited by some. For example, several at the Nottingham meeting felt that local authorities and CLARINET would have mutually benefited from a more inclusive interaction. Perhaps UK CLARINET reporting events could have been more frequent, and more widely promoted.

These limitations have been to some extent unavoidable. It was not practical to operate the European 'plenum' meetings of CLARINET as open conferences. The availability of information was limited by its reliance on the voluntary effort of many, and simply the time taken for texts to be agreed by international panels. Given that the finalisation of CLARINET documents took place during 2001, it was not possible to deliver crisp outputs to UK meetings over the course of the Concerted Action. Nonetheless, through the network of nominees (see Annex 1) the UK was able to deliver a good level of peer review of the CLARINET work. Perhaps the recent publication of the final CLARINET outputs is an opportunity that UK contaminated land conference organisers can take advantage of.

Some at the Nottingham meeting also felt that the European networking on contaminated land was restricted to those from the academic, regulatory and policy sectors. While this may be true of some networks such as the Common Forum, there are many networks, listed above, which have open participation and which would welcome new members. For example, NICOLE is actively seeking local authority and financial sector members. To a large degree, if an individual or organisation wants to get involved with one of these networks, it is up to them to get in touch, for example via the network's website.

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ever, the views expressed here should not be assumed to reflect the views of DEFRA.

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ANNEX 1. UK PARTICIPANTS AND CONTRIBUTORS TO CLARINET

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Jason Weeks	WRc-NSF
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DEFRAf	

ANNEX 2. EUROPEAN RESEARCH PROGRAMMES RELATED TO CONTAMINATED LAND AND GROUNDWATER MANAGEMENT (2001)

	Title of research programme	Managed by	WWW information
Austria	Support of studies and R&D projects for remediation of contaminated sites	Kommunalkredit Austria AG Environmental support	**www.kommunalkredit.at** **www.kommunalkredit.at/altlasten/F_E-Projekte/f_e-projekte.htm (English version)**
Belgium	OVAM R&D programme	OVAM Dienst Sanering	**www.ovam.be** **www.ovam.be/english/multilang.asp (English version)**
Denmark	The Danish EPA's technology programme for soil and groundwater contamination Various programmes	Danish EPA Cross-ministerial programme Strategic Environmental Research Programme Danish Ministry for Trade and Industry	**www.mst.dk/homepage/ (English version)** **www.dmu.dk/1_english/default.asp (English version)** **www.smp.aau.dk (English version)** **www.biopro.dk (English version)** **www.dhi.dk** **www.imt.dtu.dk (English version)** **www.GEUS.dk**

ANNEX 2. EUROPEAN RESEARCH PROGRAMMES RELATED TO CONTAMINATED LAND AND GROUNDWATER MANAGEMENT (2001) (CONTINUED)

	Title of research programme	Managed by	WWW information
Finland	Various programmes	Various institutions	**www.vyh.fi/eng/fei/fei/html (English version)** **www.vyh.fi/eng/research/r%5Fdprog/r_dprog.htm (English version)**
France	Various programmes	Ministry MATE and ADEME	**www.environnement.gouv.fr/english/default.htm (English version)** **www.ademe.fr/anglais/vadefault.htm (English version)**
Germany	National R&D programme of the Federal Administration 'Research for the Environment' (Forschung für die Umwelt)	Ministry BMBF	**www.bmbf.de/ (in German)** **www.umweltbundesamt.de/index-e.htm (English version)**
Greece	No national R&D programme, but various relevant projects	Ministries of Development and Agriculture and Environment	**www.gsrt.gr** **www.minenv.gr (in Greek)**
Italy	Various programmes, not specific for contaminated land issues	Mainly Ministry for Scientific Research, Ministry for Environment, Italian ANPA and National Research Council	**www.minambiente.it (in Italian)** **www.sinanet.anpa.it (in Italian)** **www.idg.fi.cnr.it/homeeng.htm (English version)** **http://www.murst.it (in Italian)/**
Netherlands	Centre for soil quality management and knowledge transfer	SKB	**www.bodembreed.nl (in Dutch)**
Norway	Pollutants: sources, dispersal and effects 'ProFo'	The Research Council of Norway	**www.forskningsradet.no/english (English version)**
UK	A variety of relevant programmes, though none are dedicated solely to contaminated land issues, e.g. LINK Biological Treatment of Soil and Water Programme. CLAIRE network of contaminated land sites – a public/private partnership	Three research councils, three Environmental agencies and three Ministries (includes 7 regional development agencies)	**www.bbsrc.ac.uk** **www.epsrc.ac.uk/programmes** **www.nerc.ac.uk** **www.environment-agency.gov.uk** **www.sepa.org.uk** **www.ehsni.gov.uk** **www.defra.gov.uk** **www.dti.gov.uk** **www.scotland.gov.uk/who/dept_rural.asp** **www.claire.co.uk**
EU	Fifth Framework Programme Theme: Environment and sustainable development	DG Research (D1.2) Key action: Sustainable Management and quality of water	**www.cordis.lu/eesd/src/overview.htm#3** **europa.eu.int/comm/research/fp5.html** **www.cordis.lu/fp5/home.html** **(in all languages)**