REPORT OF THE NICOLE WORKSHOP

Data Acquisition for a Good Conceptual Site Model
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www.nicole.org

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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 a range of interest groups and stakeholders (for example, land developers, local/regional authorities and the insurance/financial investment community).

NICOLE currently has 141 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 web site, newsletter and journal publications. NICOLE includes an Industry Subgroup (ISG) – with 26 members; a Service Providers Subgroup (SPG) with 40 members; 59 individual members from the academic sector/research community; and 16 members from other organisations, including research planners, non profit making organisations, other networks, 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 web sites, please visit NICOLE's web site: *www.nicole.org*.

Membership fees are currently 3,500 EURO per year for companies (1,750 EURO for smes), and 150 EURO per year for academic institutions. For membership requests please contact:

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Executive Summary

In the year of the 10th anniversary of NICOLE, despite significant progress having been made, industrially contaminated land is still a major issue in Europe. Examples of this can be found all over Europe. In the Netherlands between 9000-11000 hectares of industrial sites are obsolete. The UK has an estimated 39,600 hectares of derelict land and the stock of industrial brownfield land in France is estimated at about 20,000 hectares. Given these large quantities of industrial land it is clear that the cost-effective and efficient management of contamination and contaminated land on industrial sites is still an important subject for research and development and the sharing of ideas.

The management of contaminated land cannot simply be based upon unstructured measurements of contamination in isolated compartments of the system, such as soil and/or groundwater. Successful management of a contaminated site is based on an appreciation of the risks posed by the contamination identified to both current and future uses of the site and the surrounding area. The core of such a risk-based approach is the development and elaboration of a site conceptual model; this is the first and most essential step to ensure that there is a robust and defendable basis for contaminated land management. Data acquisition was first highlighted as a key step towards deriving a conceptual model by the 2002 NICOLE meeting in Pisa, which focused on cost-effective site characterization methods. Invited papers at this workshop in Carcassonne, southern France, presented examples from real contaminated land case studies to emphasise the importance of good quality data acquisition for the development of robust and appropriate conceptual site models, combining information on geology, biology and the chemistry of the subsoil. The emphasis was on innovative and cost effective data collection methods in support of the site management decision making processes rather than "wanting to know what is in the soil". The workshop included an excursion to the area of a former gold mine that has been undergoing an extensive remediation programme which is nearing completion. A range of presentations were given on-site illustrating some of the remediation methods tested and employed.

Owing to the number of presentations and the site visit, there was no opportunity on this occasion for an open discussion with the delegates, although each presentation drew at least some comments and/or questions from the audience. These reflections are drawn from the comments made during the workshop and further comments kindly submitted by delegates following the workshop, as well as from the questions raised by individual presentations.

Discussion

This section (and the concluding remarks) are drawn from workshop questions and answers, the closing session and further comments kindly submitted by delegates following the workshop.

A wide range of innovative, pioneering technologies and applications in site assessment were presented at the workshop. NICOLE members at the workshop had a strong interest in developing new, more efficient methods of site investigation and that site characterisation and monitoring are seen to be important and interesting topics. This interest has continued since the Pisa workshop on cost-effective site characterisation in 2002.

The most successful applications of new technologies were those linked to supplying data for a conceptual site model, for example studies which used new technology to elaborate a CSM or those which used novel technology where access using traditional methods was impractical due to logistics and expense. Presenters describing technologies without clear reference to a site conceptual model were less successful in demonstrating the value of the technology employed: in many cases the major advantage of the technique in this context was to provide a cost saving rather than providing an improvement in the understanding of the site (i.e. that it offered something to the site investigation that conventional technology could not provide). It should be emphasised that the ability to provide information at a reduced cost should not be dismissed as unimportant, as it could affect the viability of a whole site investigation project, thus the emphasis on the speed, efficiency and cost effectiveness of various technologies was unquestionably valuable.

Most of the questions raised were technical, fewer related to the application of the technology or the wider impacts of their potential adoption at a wider scale. Some of the presentations at the meeting explicitly discussed the application, and best strategy for using, innovative site characterisation, in the context of the conceptual site model. Presentations tended to focus on the detail of techniques and their cost and other advantages compared with other techniques rather than on the context of the techniques within an overall information strategy. However, a clear message did emerge about the comparative value and reliability of passive sampling and flux monitoring in comparison with more traditional concentration monitoring..

One suggestion that emerged from the Carcassonne meeting was that a workshop (or NICOLE project) looking explicitly at the process of selection of technologies, that discusses the barriers to the uptake of innovative technologies could be very useful.. It was clear from the meeting that the use of appropriate technology is essential to successful and cost-effective site investigation and monitoring. However, the selection mechanism and criteria and the technological information that industry can use are lacking at this stage. The development of guidelines for the appropriate use of technology would be a major step forward in the adoption of, or willingness to adopt new technology on a large scale. In order to achieve this, emerging technologies need to be evaluated more thoroughly; they must also be capable of being evaluated independently.

Despite the impressive results demonstrated at a trial or experimental scale in many presentations, their use on a wider scale appears limited, and there appear to be few objective comparisons of emerging techniques with each other or with established technologies. This was highlighted as a key barrier that prevents wider-scale adoption and, most importantly from an industrial company perspective, their approval by regulatory authorities. Regulatory approval is of vital importance to industrially contaminated land as industry is unlikely to take financial risks in adopting a new field measurement or analysis technology if the data from that technology will be rejected by regulators. This is a similar situation to the lack of an EU technology verification scheme for remediation technologies, a gap that is being addressed by a number of EU initiatives such as the PROMOTE project that was presented at this workshop. Therefore more emphasis needs to be placed on understanding and defining the barriers that prevent wide scale uptake of such technologies and the advantages that such technologies possess over the *status quo*.

NICOLE as an organisation has been trying to promote the development of an appropriate framework for the adoption of new technology, where it was appropriate to do so: two workshops have been conducted on themes relevant to this issue (Budapest and Barcelona). However, some concerns were expressed in post-meeting comments that there seemed to have been little change in the use of technology since the NICOLE Pisa workshop in 2002. Perhaps it is timely to support the development of "mechanisms" to move technology from the theoretical development stage, through the pioneering study stage to acceptance on an industry-wide scale, for example provision of guidance. From the current position several possible courses of action could be pursued, either by NICOLE or with the support of NICOLE:

- Initiate dialogue with industry and regulatory bodies with a view to developing a framework for technology testing and approval
- Support an effective monitoring and testing programme for new technologies that is widely accepted by all interested parties
- Support the development of monitoring guidelines for the comparison of technologies so that appropriate technology can be selected on a fitness for purpose and cost-effectiveness basis
- Emphasise the importance not only of improved data quality (in terms of cost, speed and ease of use) but also of improved use of data in terms of developing good quality site conceptual models
- Support training in and dissemination of advances in site characterisation techniques amongst service providers and regulators.

Industry is unlikely to invest in the use of new and innovative investigation technologies, even if such methods have the potential to produce improved site conceptual understanding, unless the performance characteristics and cost-benefit of the technologies has been independently verified and the data produced by the methods is going to be accepted by the regulatory authorities. By moving the situation from one of technology push-led innovation and opportunism it may be possible to achieve a smoother, more widespread adoption of innovative, effective, appropriate technologies.

It is very important that the users of new techniques and their clients are involved at an early stage in any development of programmes to verify or validate new site characterisation tools. If this consultation is left too late it will not be effective, and will lead to a project of less influence. NICOLE is an important opportunity for the developers of these proposals to converse with both their market place (service providers) and site owners (industry). Equally, regulators and those involved with policy also need to be involved from the earliest stages of project development, as a validation/ verification project that is not favoured by regulators is of little interest to service providers or industry. An inclusive approach that improves dialogue between developers, users, their clients and regulators would lead to a more efficient adoption of innovative site characterisation technologies where they could be shown to be cost-effective, appropriate and able to meet the needs of environmental protection regulations.

Conclusions

In general the meeting, the field excursion and the presentations were very well received; the issues raised by the meeting related as much to what had not been presented as to the wide range of technologies and applications illustrated. It was clear from these presentations that the chief driver for the innovative site characterisation techniques presented at this workshop is clearly cost reduction compared to existing technologies rather than improving site conceptual models. Such savings should not be dismissed as unimportant or insignificant.

It is apparent that there is a clear gap in knowledge concerning how to select the most appropriate technology. However, it was clear both from the meeting and subsequent comments that the use of appropriate technology is essential to successful and cost-effective site investigation and monitoring, despite the fact that an appropriate selection mechanism that industry can use is not available at present. To achieve this, emerging technologies may need to be compared in the context of a verification project or programme, in a similar manner to the independent remediation technology verification protocols that are being developed by EU projects such as PROMOTE. Despite the possible opportunities for more effective site characterisation that seem possible, in some presentations the extent of use and the degree of acceptability to regulatory authorities was not immediately apparent. Understanding and defining the barriers that prevent wide scale uptake of such technologies and the advantages that they possess, along with guidelines for the appropriate use of such technology would be a significant assistance in its adoption on a large scale.

It was suggested that improved dialogue between consultants, researchers, industry and regulators regarding a mechanism to move technology from development through to acceptance on an industry-wide scale would be a vital step in any process aimed at evaluating new technology.

Contents

1 Introduction

In the year of NICOLE's 10th anniversary, despite significant progress having been made in the management of industrially contaminated land, such land is still a major issue in Europe. Examples of this can be found all over Europe. In the Netherlands between 9000-11000 hectares of industrial sites are obsolete. In the UK the Office of the Deputy Prime Minister (ODPM) has a target of building 60% of new housing on previously developed land (including industrial land). The UK has an estimated 39,600 hectares of derelict land and the stock of industrial brownfield land in France is estimated at about 20,000 hectares. Given these large quantities of industrial land it is clear that the cost-effective and efficient management of contamination and contaminated land on industrial sites is still an important subject for research and development and the sharing of ideas.

The management of contaminated land cannot simply be based upon unstructured measurements of contamination in isolated compartments of the system, such as soil and/or groundwater. Successful management of a contaminated site is based on an appreciation of the risks posed by the identified contamination to both current and future uses of the site and the surrounding area. The core of such a risk-based approach is the development and elaboration of a site conceptual model. This is the first and most essential step to ensure that there is a robust and defendable basis for contaminated land management.

The emphasis of the workshop was to highlight the novel methods and techniques of data acquisition available that can contribute information which will assist in the development of robust and appropriate conceptual site models. In so doing, it is hoped that European industry will be able to identify, assess and manage industrially contaminated land efficiently, cost-effectively, and within a framework of sustainability. Data acquisition was first highlighted as a key step towards deriving a conceptual model by the 2002 NICOLE meeting in Pisa, which focused on cost-effective site characterization methods. This workshop in Carcassonne, southern France, presented examples from real contaminated land case studies to emphasise the importance of good quality data acquisition for the development of robust and appropriate conceptual site models. The workshop focused on studies combining information on geology, biology and the chemistry of the subsoil. The emphasis was on innovative and cost effective data collection methods in support of the site management decision making processes rather than "wanting to know what is in the soil".

This workshop addressed two specific NICOLE objectives, namely:

- To provide a forum for dissemination and exchange of practical and scientific knowledge;
- To stimulate collaborative research and knowledge transfer.

The workshop included an excursion to the area of a former gold mine, Salsigne, which has been undergoing an extensive remediation programme that is nearing completion. A range of presentations were given at the site illustrating some of the remediation methods tested and employed. A description of the relevant presentations (both from the workshop venue and the site itself) are included in Annex 2.

This report provides summaries of the papers given, along with conclusions based on points raised during the meeting, and comments from a number of delegates after the meeting.

Table 1: NICOLE Events and Publications from 2001

Date	Event / Report
January 2006	**Report of the NICOLE Workshop**: The Impact of EU Directives on the management of contaminated land, 1-2 December 2005, Cagliari, Sardinia, Italy. See www.nicole.org/publications/library.asp?listing=1
November 2005	**NICOLE Report:** Monitored Natural Attenuation: Demonstration and Review of the Applicability of MNA at Eight field sites, http://www.nicole.org/publications/library.asp?listing=5 (summary). The full report can be ordered from the NICOLE Secretariat
November 2005	**NICOLE Report:** The Interaction between Soil and Waste Legislation in Ten European Union Countries sites, http://www.nicole.org/publications/library.asp?listing=7 (summary). The full report can be ordered from the NICOLE Secretariat
2005	*NICOLE News* 2005 issue, www.nicole.org/publications/library.asp?listing=9
August 2005	**Report of the NICOLE Workshop**: State of the art of (Ecological) Risk Assessment, 15-16-17 June 2005, Stockholm, Sweden see http://www.nicole.org/publications/library.asp?listing=1
January 2005	**Report of the NICOLE Workshop**: Unlocking the Barriers to the Recovery of Soil and the Rehabilitation of Contaminated Land. 15-16 November 2004, Sofia, Bulgaria see www.nicole.org/publications/library.asp?listing=1 and *Land Contamination and Reclamation* **14** (1) 137-164
2004	**NICOLE Booklet** Communication on Contaminated Land, www.nicole.org/publications/library.asp?listing=2
2004	*NICOLE News* 2004 issue, www.nicole.org/publications/library.asp?listing=9
13-14 May 2004	**Report of the NICOLE Workshop**: *Sediments and sludges: an issue for industry?*, Frankfurt, Germany see www.nicole.org/publications/library.asp?listing=1 and *Land Contamination and Reclamation* **12** (4) 379-400
13 Feb 2004	**Report of the NICOLE Workshop:** *NICOLE Projects Reporting Day*, Runcorn, UK - see www.nicole.org/publications/library.asp?listing=1 and, *Land Contamination and Reclamation* **12** (3) 286 - 308
29-31 October 2003	**Report of the NICOLE Workshop**: *Sharing experiences in the management of megasites: towards a sustainable approach in land management of industrially contaminated areas*, Lille, France - see www.nicole.org/publications/library.asp?listing=1 and *Land Contamination and Reclamation* **12** (2)127-158
2003	*NICOLE News* 2003 issue, www.nicole.org/publications/library.asp?listing=9
12 – 14 March 2003	**Report of the NICOLE Workshop**: *Management of Contaminated Land towards a Sustainable Future: Opportunities, Challenges and Barriers for the Sustainable Management of Contaminated Land in Europe*, Barcelona, see www.nicole.org/publications/library.asp?listing=1 and *Land Contamination and Reclamation* **11** (3) 366-395
6 - 7 November 2002	**Report of the NICOLE Workshop**: *Financial Aspects of Site Restoration with an Emphasis on Central and Eastern Europe*, 6 - 7 November 2002, Budapest. see www.nicole.org/publications/library.asp?listing=1, and *Land Contamination and Reclamation* **11** (3) 366-395
2002	*NICOLE News* 2002 issue, www.nicole.org/publications/library.asp?listing=9
18 – 19 April 2002	**Report of the NICOLE Workshop**: *Cost-effective Site Characterisation - Dealing with uncertainties, innovation, legislation constraints*, 18-19 April 2002, Pisa. see www.nicole.org/publications/library.asp?listing=1, and *Land Contamination & Reclamation* **10** (3) 189-219
14-15 November 2001	**Report of the NICOLE workshop:** *ICT/Computing applied to contaminated land characterisation /remediation and MNA*, Rotterdam, the Netherlands (Port of Rotterdam) in conjunction with the Network on Natural Attenuation in Groundwater and Soil (NNAGS). see www.nicole.org/publications/library.asp?listing=1, and *Land Contamination & Reclamation* **10** (1) 33-59
2001	*NICOLE News* 2001 issue, www.nicole.org/publications/library.asp?listing=9

2 Presentations

Some facts and figures about the region and a brief focus on the French policy for contaminated sites *Fabrice Boissier, DRIRE, France*

The DRIRE[1] is a Regional administration of the Industry Ministry and the Environment Ministry, in charge of the implementation of environmental regulation for the industry sector (among other tasks), including the treatment of contaminated sites which are not considered as hazardous facilities. Consequently DRIRE has a significant role in the region of Languedoc Roussillon, which includes Carcassonne. The region has a rich mining and industrial history and consequently also has a legacy of contaminated soil. There are 70 sites in the region that are identified in BASOL (the inventory of contaminated sites) which require the action of the administration. There are also many sites associated with mining activity whose contamination legacy is unknown. Owing to significant population growth in the region (currently the highest in France) there is also a need to contain and manage pollution to allow subsequent urban development where possible.

A state policy on contaminated land has existed since 1993, when the requirement for an initial diagnosis and a simplified risk assessment were introduced. By 1999 the risk management policy was based on the use of the site and a detailed risk assessment. By 2003 an effective toolbox of methods existed to assess contaminated land but the application of these tools has highlighted problems and limitations. For example the tools are sometimes misused and consequently can provide misleading information. Another example is that the consequences of the onward use of the site have not always been taken into account and the construction of a good conceptual model of the problem has often been neglected.

Contaminated sites policy has now been reorganised in order to be coherent with risk prevention policies. The first goal is to contain the pollution source completely, and if that is not possible the second goal is to ensure that there is a minimal impact on human health and the environment. The technical principles of the tools (diagnosis and quantitative risk assessment) still exist in the new contaminated site policy but they have been reorganized into a two-stage process. The first stage is an assessment of the current situation, including the identification of stakeholders and that which is at stake at the site (environmental contamination and/or human health risk for example), as well as characterization of the different environmental compartments, such as soil, water and groundwater and subsequent characterization of the pollution mechanisms linking the source to the receptors. If the first stage demonstrates that further action is necessary, appropriate management plans are implemented using a new management tool, the Interprétation de l'Etat des Milieux, or IEM. The IEM is a structure for site investigation which emphasizes the importance of the conceptual model and favours measurement instead of model development. The IEM is progressive, operating in two stages. First a comparison of site data with established regulatory values is undertaken in each environmental compartment (drinking water, air quality and so on). Then, if the site data are in excess of the regulatory values, a quantitative risk assessment is undertaken to help to inform subsequent actions.

The IEM, along with further studies (past and present), contributes to the development of a conceptual model of a site and a diagnosis of the state of the environment can be made on the basis of the available information. The ultimate aim of the conceptual model is to assess whether the site is compatible with environmental and human health requirements. Having assessed and conceptualized the site, thereby identifying where the key issues are, a management plan can be developed to ensure future compliance with required standards for the end purpose envisaged, be that containment or development.

[1] DRIRE: Directions Régionales de l'Industrie de la Recherche et de l'Environnement

Setting the framework of this workshop – building a conceptual model

Wouter Gevaerts, ArcadisGedas, Belgium

A conceptual site model (CSM) can be defined as "a simplified representation of how the real system is believed to behave, without losing relevant detailed data; it implies a preliminary calculation for key processes." A key initial requirement of any CSM is data; once the data are available it is possible to use them to construct an appropriate CSM: the more extensive and better quality the data, the better the quality of the CSM. However the experience of the consultant is also important, as they are often required to make an initial assessment based on very limited information, such as a basic map and a geological profile for example. With knowledge, experience and basic site information a first conceptual model can be developed, from which an initial site characterization can be planned.

The goal of a CSM is to facilitate the assessment of risk to human health and the environment, establish a monitoring regime and provide a basis for a remediation plan for a site. It is also a means of providing a simplified, clarified understanding of the system, a means of integrating data, a framework to enable understanding of the system response and a planning and negotiation tool based on the assessment of potential risk.

The first stage of CSM development is the acquisition of both readily available and new data. The ultimate aim of such data collection is to try and identify the main sources, pathways and receptors of pollution both within and beyond the investigation area. Key data requirements are information about current and/or past industry, sources and sinks of pollution, water levels, hydraulic properties and the geological framework within which the other factors operate. These can be categorized into four key aspects, or layers, of a conceptual model: geology, hydrogeology, microbiology and the contaminants. Examples of specific data requirements in each category (which will vary on a case by case basis) are as follows:

- GEOLOGY: micro-porosity grain size, heterogeneity, mineralogy, chemistry, macroporosity
- HYDROGEOLOGY: effective porosity, permeability, redox conditions, hydrochemistry
- MICROBIOLOGY: bioavailability, redox, species, nutrients
- CONTAMINANT: solubility, biodegradability, polarity, volatility, complexing

These four key aspects of the model interact with and are affected by land use, not only in terms of the contaminant source, but also in terms of topography and potential receptors. Having assessed the key areas of the model and related them to surface activity and characteristics an estimate of spreading risk of the contaminant can be achieved. These core factors must be considered in the context of surrounding issues such as finance, communication and legislation, which will also influence land management and remediation decisions. These relationships are illustrated in Figure 1.

Further issues to consider are the influence of time and scale. On a human timescale geology will not change, whereas factors such as hydrogeology, microbiology, chemistry, as well as the wider factors such as legislation and finance will all change to a greater or lesser extent. They will also change at a slower or quicker pace relative to each other. These changes may or may not affect the validity of the model and the influence they could have should therefore be considered, although it is unlikely they could be included in the model itself. These can operate at a variety of scales. For example aerobic and anaerobic conditions can occur on the scale of a groundwater plume or could equally be an influence at a micro scale, aerobic and anaerobic conditions existing and influencing contaminant transport at the soil pore scale.

The most important stages in CSM development are defining the purpose of the project (monitoring, RA, remediation), compiling the data (bearing in mind that outliers may be significant indicators), constructing a model, quality control (quantitative assessment and assessments of uncertainty in the outcomes) and to revising the CSM in the light of the results of the quality control tests. The process is illustrated in Figure 2. Important considerations during the CSM building process are how well it describes the important processes operating within the system, whether the complexity of the CSM is consistent with both the required objectives and the budget and data requirements. All models are simplifications of reality therefore they all have limitations, or can simply be wrong; this does not necessarily invalidate their use, but it is important to be aware of what could be wrong in the model and to consider whether any such limitations are important in the context in which the CSM is being used.

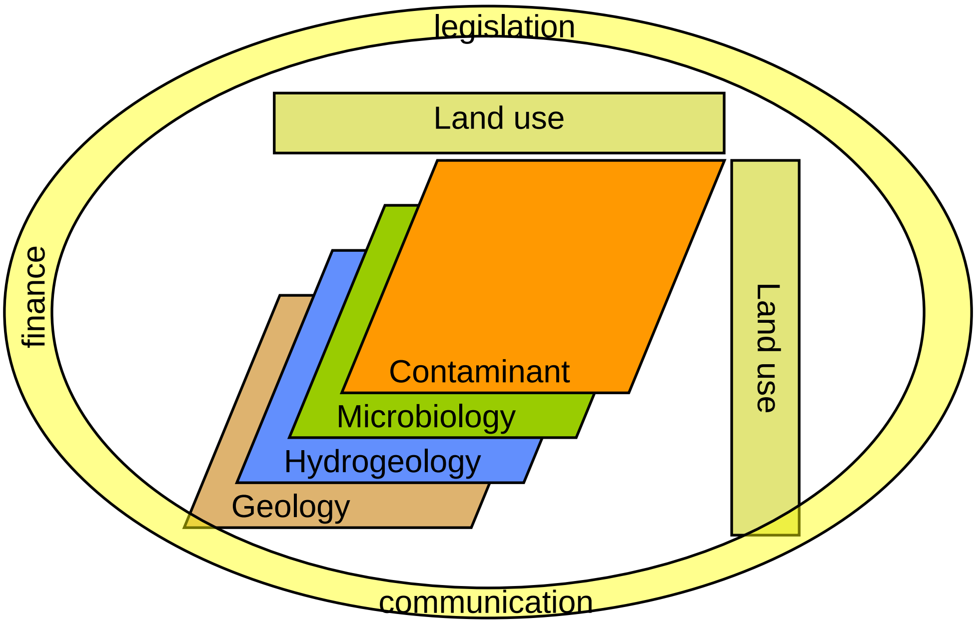

Figure 1: Illustration of the inter-relationships between key aspects of a CSM

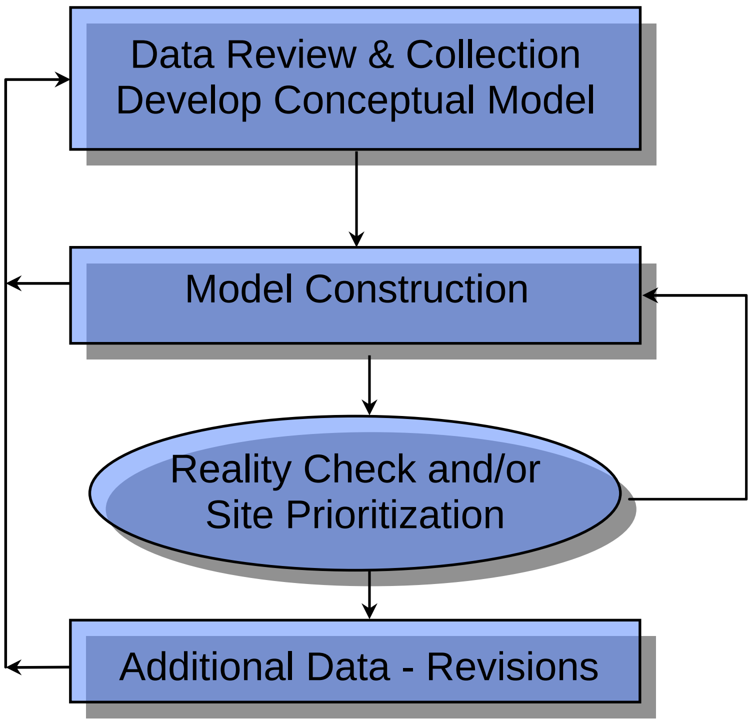

Figure 2: Model building procedure

Comparison of different technologies for geological site characterization with examples from different sites *Peter Dietrich, Centre for Environmental Research (UFZ), Germany*

A wide variety of investigation approaches can be employed for geological characterisation of sites. These include gravimetrical methods, geomagnetic methods, geoelectrical resistivity methods, electromagnetic methods, seismic methods, geothermal methods, radiometric methods and nuclear physical methods, each of which has their advantages and limitations. For example boreholes may miss important detail if a site is highly variable over a relatively short distance and extra boreholes would be a costly means of overcoming the problem, while geophysical surface measurements have a variable resolution depending on the method employed. In addition such measurements do not provide information on properties such as hydrological connectivity. When conducting a site investigation it is therefore important to consider what information is required (geological data, chemical data or hydrogeological data for example) and what measuring technique, or combination of techniques would best suit the data requirements and site conditions.

Direct push (DP) technologies can combine several forms of sampling and measurement together, a system which can help to obtain relationships between different data streams. As an example a DP system could obtain electrical conductivity, contaminant and hydraulic conductivity data simultaneously and also obtain groundwater, soil and soil gas samples. A variety of comparative experiments from three site investigations in Germany were presented to illustrate the relative performance of DP techniques in comparison with alternatives. These are described briefly below:

1. A variety of DP measurements were used and compared for the characterization of hydraulic conductivity; these included electrical conductivity, injection logging (DPIL), slug tests and permeameter (DPP) measurements. The data from each of the measuring techniques showed a good relationship between each other, but each technique has advantages and disadvantages, as illustrated in Table 2.
2. A comparison of DP methods with surface geophysics as methods to quantify contaminant degradation and retention properties under field conditions. In this case the trade off was between fast and relatively cheap geophysical methods and more expensive and slower (four days as opposed to three hours) DP methods. In this case the DP methods proved to have the advantage of greater accuracy.
3. A comparison of colour tracer tests and geoelectrical tracer tests for their ability to measure groundwater velocities.
4. A comparison of tracer tests against geophysical site characterizations as a means of identifying sediment structures and predicting transport behaviour.

These examples illustrate that all methods of data acquisition have advantages and disadvantages in terms of the range, reliability and quality of data they can produce, as well as the time it takes to acquire the data and their relative cost. Using different kinds of logging tools at the same location can overcome the limitations of individual measurement techniques and to determine site specific relationships between geophysical, geotechnical and hydrogeological parameters. Direct Push can be a very useful supplement for borehole and surface measurements. Geophysical methods are suitable for spatial continuous exploration of structure and monitoring of processes in the subsurface. The combination of Direct Push technologies and geophysical measurements can significantly increase the quality of subsurface characterization at considerably less cost than the use of additional boreholes.

One result of this work has been the development of a research platform called MOSAIC[2]. It follows the conclusions of the field comparisons by combining two components. The first is a Direct Push tool containing an EC-log, an MIP-log, an injection-log, a permeameter, slugtest, SPT-log and soil, gas and

[2] Model Driven Site Assessment, Information and Control

water samplers. The DP probe is mounted on a vehicle which tows a trailer containing the second half of the analytical equipment, namely seismic geoelectrical, georadar, gravimetric, magnetic and radioactivity sensors. The equipment was used in conjunction with a borehole logging unit and hydrogeological equipment such as a pressure transducer and tracer testing equipment. The ultimate aim of the MOSAIC system is the delineation of major subsurface units with detailed information about their internal structure.

Table 2: comparison of the advantages and disadvantages of DP methods for measuring hydraulic conductivity.

	Determ. of K-value	Speed	Robust-ness
EC logging	Site specific	Continuous	Very high
Injection logging	Relative	Ca. 1 min/MP	high
Slug test	Absolute	Ca. 60 min/MP	Very high
Permeameter	Absolute	Ca. 10 min/MP	Low
Injection logging + Slug tests	absolute		high

Innovative geological and hydrological characterization in support of a MNA approach at an industrial site *Thomas Keijzer, Tauw, The Netherlands*

The site investigation presented was based at a large industrial unit using chlorinated solvents (TCA[3] and DCA[4]), which were present as DNAPL[5] pools underneath the site. The industrial unit itself was located close to ecologically significant estuarine surface water. The surface water channel was bounded by a levee, which meant that boreholes could not be placed in this zone. A further feature of the location was a small landfill site and waste management facility for permanent waste storage adjacent to the site boundary. The concern at the site was whether the contamination was migrating beyond the site boundary and whether or not this posed an unacceptable risk to the surface water.

Available data showed that at 10 metres below ground level contamination was contained immediately below the known source within the site boundary. At 10-20 metres below ground level minor contamination beyond the site boundary and beneath the waste management facility was evident, while at 20 to 30 metres below ground level high levels of contamination were observed at the edge of the site boundary and very high (400,000 μg/l) levels of contamination were found beneath the waste management facility. In summary, there was evidence for DNAPLs between five and 31 metres below ground level. The area had a complex hydrology due to the influence of saline groundwater and there was the possibility of migration of DNAPL on the slanting aquitard at approximately 30 metres depth.

The aims of the study were to develop a conceptual model of the contamination, with a focus on the site boundary. The intention was to delineate the contamination, to assess contaminant flux beyond the site boundary and to assess whether the DNAPL was moving. A further aim was the assessment of the

[3] Trichloroethane
[4] Dichloroethane
[5] Dense, non-aqueous phase liquid

feasibility of remediation measures, of which the preferred option was Monitored Natural attenuation (MNA). The methods employed were a combination of Direct Push (CPT[6] combined with Membrane Interface Probe (MIP) using PID[7], FID[8] and DELCD[9] detection, and conductivity), hyderogeochemistry (Groundwater dating via analysis of CFC[10] & SF_6[11]) and geophysics (interpretation of geotechnical information from 1965).

These different monitoring techniques were applied at 15 locations along two transects along the site boundary, one adjacent to the surface water, the other adjacent to the waste management site. The MIP data did not show any evidence of DNAPL down-gradient of the source zone, but they did indicate plumes at the site boundary, at the fresh/saline water interface and on top of the aquitard. The CFC groundwater dating technique was not usable on the site, but the age based on SF_6 corresponded well with that predicted by hydrological modelling. On the basis of the MIP results combined with the age dating of the groundwater reliable estimates of contaminant mass at the site boundary could be made and field degradation rates estimated. In addition, when combined with historic geotechnical data for the site it was possible to identify layers of low permeability.

The additional data was used to improve the conceptual model of the site (Figure 3). The core source of pollution was immediately below the installation: the plume descended vertically, passing through a discontinuous clay layer at six metres depth and a further layer at approximately 15 metres depth.

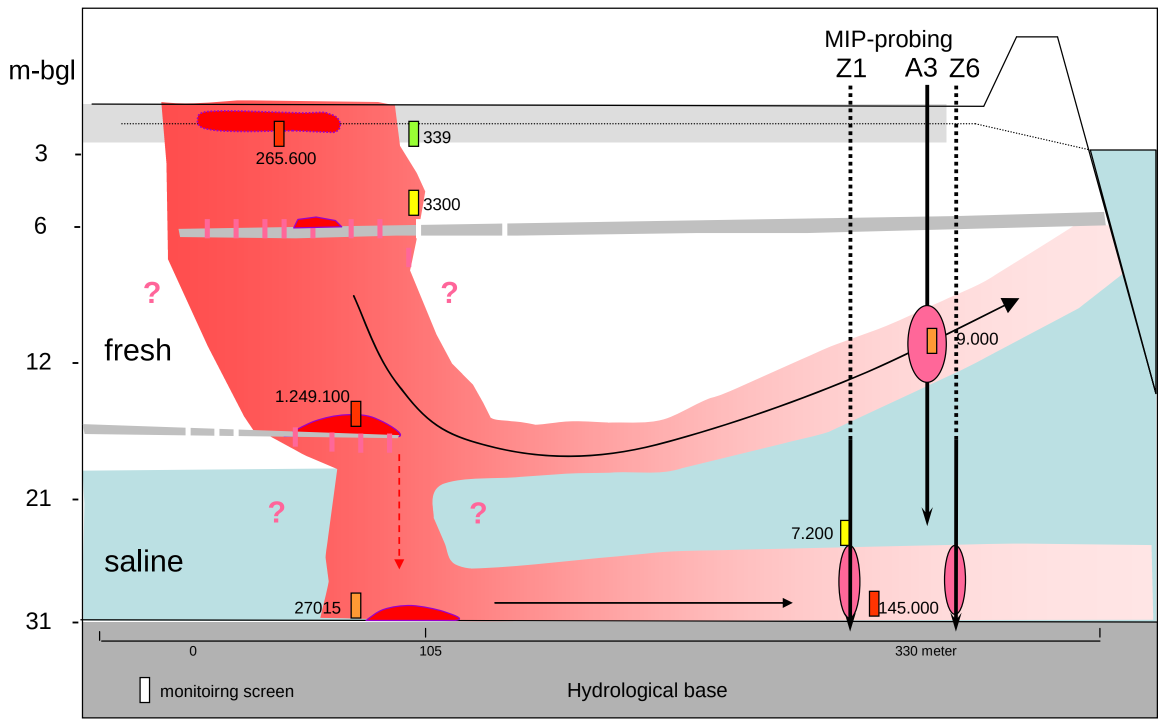

Figure 3: Site conceptual model

Some accumulation of DNAPL occurs on these boundaries, particularly the lower of the two. Migration of the contamination towards the surface water occurs in two plumes, one at the fresh-saline water boundary and the other at the boundary of the aquitard, although the transfer of contamination is

[6] Cone Penetration Testing
[7] Photoionisation Detector
[8] Flame Ionisation Detector
[9] Dry Electrolytic Conductivity Detector
[10] Chlorofluorocarbon
[11] Sulphur Hexafluoride

relatively low (Figure 3). Despite the improvements in the conceptual model there are still some uncertainties in relation to the distribution of the contaminants, as indicated by the question marks in Figure 3.

The site investigation has shown that a combination of Direct Push, geochemical and geophysical data can be successfully applied to improve delineation of a contamination and estimates for contaminant flux at sites with complicated hydrogeology, resulting in an improved conceptual model of contaminant migration. There was no evidence for DNAPL migration as the result of aquitard slope, however there was plume migration at fresh water/saline water interface and on top of the aquitard. Based on the MIP results reliable estimates of contaminant mass at site boundary could be made and could be used to estimate field degradation rates. The contaminant fluxes in both fresh and salt water at the site are acceptable for MNA.

Chlorinated compounds detection in soils and water with geoelectrical methods *Jean Christophe Gourry, BRGM, France*

Since the end of the 1980s developments in geophysics have allowed its use in the detection of pollution sources and plumes in soils and water. Except for metallic pollutants where a magnetic method is usually recommended, geoelectrical and electromagnetic methods are now the most common methods used for the detection of organic pollutants such as hydrocarbons and chlorinated compounds. For the detection of chlorinated compounds Complex Resistivity (also called Spectral Induced Polarization) and Ground Penetrating Radar (GPR) are the most effective techniques, but GPR is usually inapplicable because of the low resistivity of shallow terrain that attenuates electromagnetic waves. The Complex Resistivity (CR) method injects alternative current into the ground at specific frequencies (typically from 0.1 to 100 Hz) and measures magnitude and phase potentials via two receiving electrodes. Calculated resistivity and phase readings are then computed to obtain maps or vertical cross sections that can be interpreted as appropriate. Chlorinated compounds mixed with clayey material create a large phase shift at certain frequencies. Alternative methods of measuring chlorinated compounds in the field include gas analysis at the field surface, using a portable Photo Ionisation Detector (PID) or an Infra-red (IR) detector, or with a field-size gas chromatograph (GC).

Preliminary research from two sites in Italy and Belgium measuring chlorinated compounds, hydrocarbons, heavy metals and acid mine drainage using a combination of CR, PID, IR and GC were presented.

The Italian site is located in a factory at Porto Marghera near Venice. Situated in an ancient lagoon, the geology is made up of horizontal layers of sand and silt, cut by palaeochannels. There are two aquifers; the shallow aquifer (1-2 m) is contaminated with TCE, DCE and PER. An impermeable clay layer protects the second, deeper aquifer from pollution. A CR survey in an area suspected to be polluted showed high phase anomalies (more than 200 m radius) at frequencies higher than 20 Hz, whereas low phases have been measured at low frequencies. A conductive lineament has also been recorded in this area. After the survey, boreholes were drilled to verify the interpretation. The areas identified by phase anomalies were in fact heavily polluted with chlorinated compounds (TCE concentrations were higher than 2000 mg/kg in soils). The conductive zones, where the contaminant plume was circulating were filled with palaeochannel material, indicating a preferential flow route for groundwater and associated contamination. High conductivities were measured in these ancient palaeochannels as the chlorinated compounds degraded into chlorides, providing further evidence of the link between the palaeochannels and contaminant transport.

Preliminary data from a second site in Belgium was also presented. The site consisted of a group of settling basins associated with a PVC factory. The basins were filled with lime, and covered with backfills. An impermeable barrier composed of clay and schists was located at 11 metres below ground level, while the water table was situated at 7 metres below ground level. A gas analysis survey with a portable Ecoprobe 5 analyser showed localized anomalies (figure 2). A CR profile was subsequently carried out on the site (figure 3). The conductive material below the water table was the result of high chloride concentrations. There is a reasonable correlation between phase anomalies and PID on the basis of preliminary testing and further investigations to confirm the initial findings, including a more detailed survey and verification boreholes and analyses, will be carried in the coming months.

The results of the investigation thus far have shown that non destructive techniques can be used for the detection of sub-surface chlorinated compounds in soils and water. A portable gas analyser with a PID detector is easy and fast to use in the field and gives a good idea of the distribution of chlorinated compounds in high concentrations. The Complex Resistivity method is a new geophysical technique where phase anomalies show the location of chlorinated compounds and low resistivity zones show the location of chloride paths, allowing both identification of the presence of the compounds and their likely route through the sub-surface. The Complex Resistivity method has the advantage that it can provide horizontal maps as well as vertical cross sections, which enables the site investigator to see the vertical repartition of chlorinated compounds. The use of the technology has been demonstrated at two sites, although this work is ongoing and some of the data are provisional. Further research in the field is needed to validate the use of the technique.

Overview of technologies *Ludo Diels, VITO, Belgium*

The presentation began by asking the question whether it is possible to judge if microbiology is the activity responsible for natural attenuation and/or biodegradation processes. It considered three in-situ biological technologies that might be monitored. These were Natural Attenuation (due to the presence of electron acceptors and/or donors), Biostimulation (the injection of electron acceptors/donors or nutrients) and Bioaugmentation (the extra injection of micro-organisms, either in a Reactive Zone (RZ) or a Permeable Reactive Barrier (PRB)). The subsequent question posed was how might such techniques be monitored? It was suggested that sampling of soil, sediment, water and interstitial water could be achieved by batch, column, or in-situ mesocosm sampling, while bacterial activity could be measured by biodegradation of the pollutants in question. The bacterial community could be monitored on either a species- or gene function-specific basis. The presentation focused on the application of the *in situ* mesocosm technique using an *in situ* mesocosm sock, a device which has the advantage that it employs the actual material from the site at the site while allowing for easy monitoring. This avoids transferring material to the laboratory, which results in data that is not representative of real conditions.

Investigation of pollutant transfer at the molecular level allows monitoring at a very fine scale, allowing a very precise definition of the interface between polluted groundwater and surface water. This was illustrated with reference to a case study designed to assess the potential for the degradation of CAH[12] through dehalogenation at the groundwater-surface water interface. The study took place at a site on the River Zenne on the outskirts of Brussels, a highly eutrophic stretch of river due to the input of industrial effluent and untreated sewage. The site was adjacent to a large industrial area where groundwater flow was in the direction of the River Zenne and a significant CAH groundwater plume underlay several point sources of PCE and TCE. Monitoring was undertaken at several points along the Zenne where it was adjacent to the groundwater plume. At each point samples were taken at three points in the river bed (left, centre and right) using a piston aquifer sampler. Pore water samples also taken using Teflon pore water samplers at varying depths in the sediment (20, 60 & 120 cm). Monitoring wells at the side of the river were also sampled.

[12] Chlorinated Aliphatic Hydrocarbons

In the laboratory degradation potential was assessed in a two-stage process. First, Polymerase Chain Reaction (PCR) and DGGE[13] analysis was used to detect the presence of the relevant dechlorinating bacteria and dehalogenase genes at the DNA level. Secondly anaerobic batch degradation tests on microcosms were undertaken to assess degradation activity. Microbial degradation potential was characterised by molecular techniques, including an assessment of the structure of the microbial community (general 16 S rDNA-primer), and the diversity and expression of catabolic genes. At the study site it was hoped that it would be possible to observe and examine natural attenuation at the interface between groundwater and surface water (anaerobic dechlorination in eutrophic sediment).

Results from the first stage of the assessment (detection of bacteria and dehalogenase genes by PCR) indicated that different types of bacteria were present in different quantities at different depths of sediment. All were capable of biodegradation, but not of the same substances, nor necessarily at the same rate. The anaerobic batch degradation tests to assess the effectiveness of the bacteria in degradation demonstrated that the bacteria were actively biodegrading pollutants as well as being present. The activity of the bacteria was affected by the presence of electron donors, which in turn were affected by the addition of phosphates, lactates and molasses. All of these substances were present in the natural system and were supplemented by the enhanced eutrophic conditions present in the stream.

The conclusion of the case study was that a combination of a variety of monitoring techniques was capable of demonstrating that dechlorinating bacteria and dehalogenase genes were present in the sediment of the river Zenne and that they were actively degrading pollutants present in a groundwater plume from an adjacent industrial facility. As a result they became part of a Natural Attenuation barrier between the polluted groundwater and the surface water above. In terms of the technologies employed, *in situ* mesocosms allowed monitoring of sediment and water within an aquifer, while interstitial water sampling was undertaken using teflon pore water sampling equipment. Monitoring of the bacterial community was achieved using DGGE to identify general primers and PCR to identify individual species. Stable isotope fractioning was used to identify pollutants and to assess the proportion of surface water and groundwater in a sample. The combination of all the techniques gave a powerful means of acquiring knowledge of bacterial degradation at the molecular level.

Biological investigation and monitoring tools used at a site contaminated with chlorinated ethylenes *Maurice Henssen, Bioclear, The Netherlands*

Recent years have seen the development and evaluation of various tools designed to determine and quantify biological processes operating within the soil. These include degradation tests, molecular DNA screening, intermediates analyses and assessment of kinetics in contamination remediation and site investigation. A key benefit of these tools is that they can optimise site investigation, especially where they are used at an early stage of the process, ultimately resulting in a more cost-effective remediation programme. For example studies determining the presence of specific organisms in the soil using DNA analyses have shown a very good correlation between the appearance of specific organisms, conditions in the soil and degradation capacity; the analysis therefore provided additional information about the site at no additional cost. A further important advantage of biological parameters is that a large quantity of information about the overall state of a site and the possibilities for remediation can be obtained using relatively few observations of a limited range of parameters. Biological parameters aim to give insights into possible solutions, unlike parameters measuring the location and the concentration of contaminants for example, which focus on the problem itself. Thus incorporating biological parameters and/or measurements into a site investigation at an early stage gives the possibility of coming up with effective solutions and a clearer understanding of which parameters are most important to measure. This results in decreased site investigation time and costs as well as greater efficiency.

[13] Denaturing Gradient Gel Electrophoresis

Three examples from the Netherlands were used to illustrate the value of biological measurements in site investigation. The first, in the town of Appingedam was located at a dry cleaning facility in an area known for such facilities both historically and at present, where there was evidence of significant polychlorinated ethylene (PCE) contamination of groundwater underneath the buildings in the area. Owing to a range of site-specific circumstances it was either difficult or impossible to investigate and treat the area using traditional methods. The soil layer up to 9 metres below ground level consisted of clay and peat layers that were difficult to treat. Excavation or pump and treat would have been difficult and expensive as the area is highly built up. As a result of vertical transport the chlorinated ethylenes had reached a sandy layer situated at 9 metres below ground level, in which a plume of approximately 150 meters had developed.

Although logistically difficult, the remediation plan at the site consisted of an expensive permanent pump and treat of the plume area. An alternative option was to encourage degradation in the core zone and to reduce transport to the sandy layer. The conceptual model of the site was that the contamination biodegraded via NA (the half life of PCE is approximately 300 days) but at a rate which was too slow to prevent migration from the core pollution area as a result of groundwater flow. The proposed solution was to enhance degradation rates to increase the quantity of biodegradation near the source, reducing migration from the site in the groundwater plume. Batch experiments were performed to obtain information about the biological capacity of the soil, particularly in the core zone of pollution with the highest concentrations. It was concluded that despite the high contaminant concentrations, degradation in the core zone was occurring and that degradation rates could be increased by a factor 5-7. The remediation plan was changed into a biological *in situ* treatment involving the direct injection of approximately 1000kg of carbon sources in the form of lactates, molasses and nutrients. This reduced remediation time to 10-12 years and reduced costs by approximately half. Ongoing monitoring of the plume between 1998 and 2005 showed that it reduced in size dramatically and that by 2005 the pollution was effectively contained in the core pollution zone. The monitoring was undertaken using new molecular tools (DNA analyses) that were used to obtain insight in the appearance and development of specific, contaminant-degrading organisms. As this was an indicator parameter the total set of parameters to be measured was optimised, resulting in reduced monitoring costs. This case was a good example of using biological tools to obtain information which gives a solution to the problem at a very early stage. In this case this solution was cheaper than the conventional technique and remediation could be monitored very effectively using the molecular monitoring tools.
A second site at Vries was highly contaminated with benzene, as well as other aromatics such as phenols and benzoates. Monitoring of the redox parameters at various sites that are contaminated with BTEX[14] aromatics often show a consumption of different electron acceptors, indicating natural biological processes. In the case study at Vries, the consumption of sulphate and the presence of intermediate products like benzoates and alkyl phenols clearly indicated the occurrence of natural attenuation. However, it also proved that the biodegradation of BTEX aromatics was limited because of a lack of sulphate in the source zone. The approach to the problem was to inject nitrate and sulphate into the ground in the direction of groundwater flow to act as electron acceptors and stimulate biodegradation. At the time of the presentation limited data were available to show degradation at the site but the successful deployment of the technique was illustrated with data from a plume at another site.

A third case study from Almelo was also shown. In this case the area had neutral to slightly acidic pH conditions, contamination by PCE and high levels of sulphate and TOC[15]. However, no biodegrading organisms were present on the evidence of molecular screening tests. Remediation through air sparging had previously proved unsuccessful. In this case the *in situ* bioremediation process involved the direct injection of biodegrading organisms to stimulate dechlorination. The effect of this process was shown in monitoring data for the period from February 2004 to November 2005, during which

[14] Benzene, toluene, ethylbenzene, xylene
[15] Total Organic Carbon

time benzene pollution decreased dramatically and the site was effectively remediated. There was, however, an increase in the presence of degradation products, which in itself was indicative of a process of accelerated biodegradation. In this case the biological investigation and monitoring tools were used to determine remediation strategy, design an optimal plan and to monitor the process very effectively.

These case studies provide a powerful illustration of the potential value of biological measurements for providing an insight into site contamination that can be used to create remediation solutions which are often more cost-effective and quicker than traditional methods such as air sparging or pump and treat.

Bioscreen monitoring and molecular characterization *Nanne Hoekstra, TNO, The Netherlands*

The presentation described an extended pilot-scale study of the effectiveness of a bioscreen in controlling contamination by TCE and TCA from a former metal workshop of a car and truck manufacturer. The site was underlain by heterogeneous materials, a mixture of fine sands, silt, peat and clay. Groundwater flow was close to the surface (1-2m) underneath the site then descended in a cork-screw fashion via natural funnel to an aquifer at a depth of approximately 40 metres below ground level (Figure 4). The soil and groundwater were contaminated with TCE and TCA and their associated degradation products. Degradation in the soil below the site was limited due to the lack of electron donors. This, in combination with the rapid flow in the aquifer (40-50 metres per year) meant that the plume was extensive, although contamination was variable along its length, TCE being close to the source and vinyl chloride being furthest away (approximately 1,000 metres), which indicated a natural biodegradation process operating within the groundwater flow. The source of contamination was beneath an important production facility, which negated the possibility of demolition to allow access for remediation: the source area itself was complex and extensive, having several hotspots, making remediation at source difficult. However, the groundwater plume was reasonably accessible at a shallow depth close to the source of contamination, before it descended to the depth of the aquifer and the contamination was transported off-site. This provided the ideal location for a trial bioscreen to assess the effectiveness of the technology for resolving the problem (Figure 4).

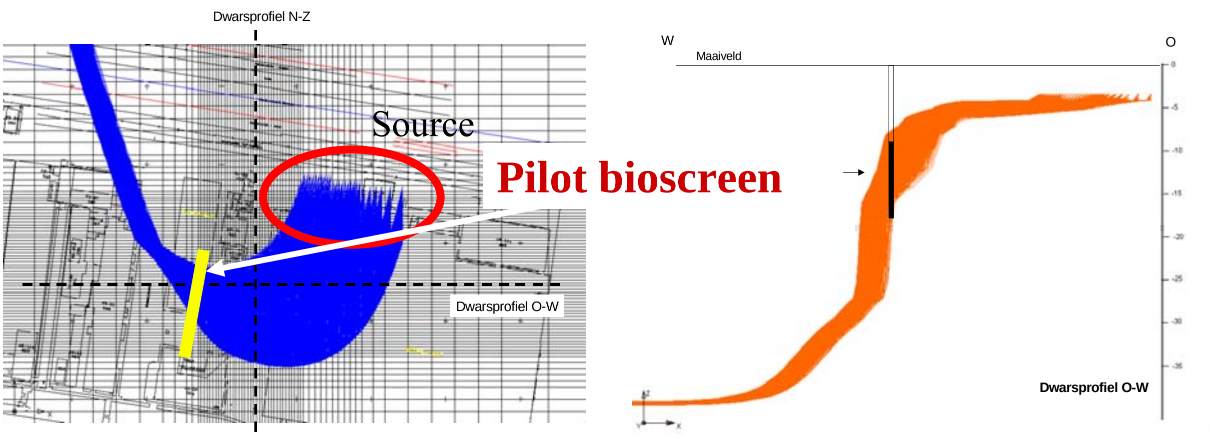

Figure 4 Form of the groundwater plume and location of the bioscreen

The bioscreen was installed at the natural funnel of groundwater flow at 10-15 m depth (see Figure 4) in February 2001. Contaminated groundwater was extracted, an electron donor added to act as a substrate and the water returned. Three monitoring wells, one between the extraction point and the bioscreen and two beyond the bioscreen, were sunk to assess its performance. After approximately 21 months (November 2002) the bioscreen was functioning effectively, stimulating biodegradation of

TCE and TCA to ethane and ethene across its boundary. The forecast effect of the bioscreen on vinyl chloride pollution will be to remove the plume in a period of over 60 years.

Although a variety of techniques (high resolution sampling on heterogeneity redox zones, modelling of the current plume, microcosm experiments and molecular analyses) do not conclusively demonstrate the existence of natural biodegradation in aquifer, an analysis of flow path data of stable isotope numbers supports the argument that biodegradation is occurring. Examination of data from one of the wells downstream of the bioscreen indicates that since the installation of the bioscreen, microbial activity has emanated downstream of the screen itself and is also occurring in the groundwater plume.

An important conclusion of the work to date is that investment in high quality site characterization and monitoring can lead to major savings in site remediation costs by identifying where natural attenuation is effective, although, of course, there is no absolute guarantee that they will definitely prove natural attenuation is taking place. The bioscreen was found to be a cost effective solution, which was because of the sophisticated monitoring that under-pinned it. The zone of effect of the bioscreen interventions also penetrated into the contaminant plume, leading to a shorter plume life.

A fast screening method for determining the extent of zinc ash contaminated soils on the De Kempen megasite *Thomas Keijzer, Tauw, The Netherlands*

De Kempen is a large region (2,600 km^2) in the south-eastern part of the Netherlands and the northern part of Belgium. Between 1892 and 1974 six smelting operations were based in the area. Heavy metal industries are still based in the region but they are now subject to far greater restrictions. As a result of the long established industry in the region, contamination of the soil and groundwater with heavy metals, in particular zinc (Zn) and cadmium (Cd) is a significant problem. Sources of contamination include atmospheric deposition, discharge from sites and the widespread use of ash and slag from the smelters in the construction of roads, farm yards and so on. This last source of contamination formed the focus of the study.

The aim of the project was to undertake a rapid reconnaissance survey of the road network to identify specific areas of concern for zinc contamination from the ash and slag used in roads, the surface layer of which is gradually being removed and replaced. The study was commissioned as blind test to compare the data with previously acquired survey data to determine whether it was possible to survey the presence of Zn-contaminated soil and roads contaminated by Zn ashes and slag, whether it was possible to determine the volume of the Zn-contaminated soil and whether the new system was faster, cheaper and comparable with traditional methods.

The operation used a device known as Medusa[16], a γ-ray detector which detects naturally occurring radionuclides of potassium, thorium and uranium. This detector combined with ground penetrating radar (GPR), acoustic sensor, pressure transducer and a GPS[17]. The combined data can be used to interpret differences in soil texture such as sand or clay, soil stratification, road surface wear and stratification as well as differentiate between Zn- and Cd-rich and other materials. The whole unit was mounted on the back of a car, which allowed measurements to be taken at a speed of up to 100kph along the roads being studied and therefore resulted in a very rapid reconnaissance of the site. In this case the measurements were taken along predefined lines (road sections), although the device has also been used in fields or along stretches of watercourses (for assessing sediment quality in rivers and canals to reduce the quantity of unnecessary dredging).

[16] Multi-element Detector system for Underwater Sediment Activity
[17] Global Positioning System

Early results indicated that the Medusa sensor was able to detect significant differences in the characteristics of zinc ash in comparison with sand, sludge, chippings and gravel (Figure 5). Subsequently a series of tests on roads around the town of Sterksel were undertaken; an area of this site had also been surveyed traditionally and could therefore be used for comparative purposes. On its own the Medusa data identified variations in signal, which could be explained by zinc ash contamination, but which could also be explained by variations in road and subsoil stratification. When combined with GPR data, which gave information on the stratigraphy, the data were able to identify sections of roads with high levels of chippings and ash.

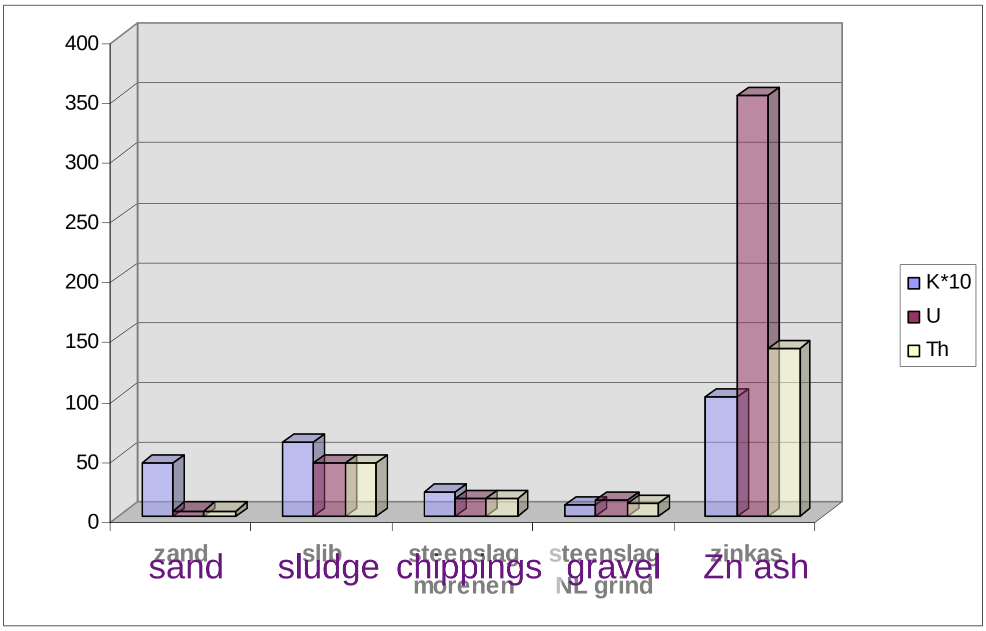

Figure 5 Medusa sensor data for different substances found in and under the road surface

The combined data yielded information about differences in stratification of roads and verges, which can be used to identify the location of ‘anomalous’ areas, which are likely to be high in zinc and cadmium contamination. However the quantity of calibration was insufficient to be absolutely certain of the results: more samples are needed to interpret the field data GPR and to quantify the thicknesses of different layers and thereby the volumes of the anomalous areas.

Conclusions of the work to date are that it is possible to survey the occurrence of Zn ashes and/or slag underneath roads and verges using the Medusa sensor. Used in combination with GPR and selective sampling it is possible to determine the volume of Zn contaminated soil volumes. The method is also faster and cheaper than conventional sampling and analysis, but as yet the data are not directly comparable. Further work aims to improve calibration by increasing the number of lab reference measurements of Zn ashes/slag, to assess whether there is an added bonus in including other geophysical techniques (such as metal or conductivity detectors). A final aim is to convince competent authorities of the usefulness of the method.

What is needed to get trust in a technology? *Derk van Ree, GeoDelft, The Netherlands*

The problem of the contamination of land and groundwater by industrial activity is highly significant from the point of view of the area affected, the potential clean-up costs and the management implications for businesses and the authorities. During the period 1999-2002, the annual expenditure on the clean-up of contaminated land in different European countries varied between € 2 and € 35 per capita per year. In coming decades the accumulated expenditure will run into tens of billions of Euros.

A large percentage of the total costs of site management are made up by characterisation and monitoring, which are essential steps in land management. A desire to reduce these costs has led to much research, development and subsequent improvements in the fields of monitoring, site characterisation and remediation for soil and groundwater. Businesses and authorities strive to identify and manage contaminated land problems responsibly and cost-effectively. However, this desire for improvement could be limited by a lack of awareness of the full range of available innovative environmental technologies and a limited understanding of the scientific and technological aspects of new developments. Decisions over the selection of appropriate technologies for a specific situation should be made in the light of as much information as possible, especially when such decisions are the ultimate responsibility of a non-expert. At present the acceptance of innovative technologies is low, despite the fact that they can be very effective in reducing of both time and cost. The reasons for this vary with each case, but the issue raises the question 'what is needed to get a trust in technology?'

To remove barriers to the implementation of new innovative environmental technologies the European Commission has developed an Environmental Technology Action Plan (ETAP). European nations have a good track record in the development and application of environmentally sound remediation technologies. To capitalize on this strength and remove some of the barriers to development that have been identified, DG Research and DG Environment are supporting activities specifically related to the development and demonstration of a European Environmental Technology Verification system (EETV). The system would improve buyers' confidence and support innovation by means of independent verification by a recognized body in an objective and transparent way, thereby helping convince the market of the merits of the technology. The aim would be to establish or prove the truth of the performance of a technology under specific predetermined criteria or protocols and adequate data-quality assurance procedures. This would be followed by prototype testing, pilot testing, demonstration, verification and certification. This process is often very difficult for individual producers, especially SMEs, due to high costs. Although ETV in the sense of the system operated in the USA does not exist in Europe, the European Commission is supporting the development of verification systems for different types of environmental friendly technologies, through encouraging the collaboration between a variety of European initiatives and R&D-projects including:

- PROMOTE soil and groundwater site characterisation, monitoring, remediation
- TESTNET water treatment technologies
- EURODEMO Concerted Action efficient soil and groundwater remediation
- AIRTV (air treatment technologies, under negotiation)

By means of a common advisory board between these projects and joint consortium meetings, issues and approaches are linked to each other to strengthen the overall approach. The directors of both the American and the Canadian ETV-programmes participate in the advisory board to offer their experience in support of the individual EU funded projects and initiatives aimed at improving the uptake of innovative technologies. DG Environment and the Joint Research Centre IPTS in Seville have undertaken feasibility studies for the design and implementation of a fully fledged EETV system, looking into organisation, running costs and industry interest and willingness to pay. It is intended that any future EETV system should be vendor driven.

The presentation focused on the PROMOTE project, funded within the 6th Framework Programme. PROMOTE started in September 2005 and will last three years: the structure of the project as shown in Figure 6. The aim of PROMOTE is to set up an efficiency control and performance verification system for soil-groundwater protection and rehabilitation based on a more generic testing and performance verification concept, in a network of testing centres. The system is aimed at verification, which is defined as the establishment or proof of the performance of a technology under specific predetermined criteria or protocols and adequate data-quality assurance procedures, with reference to predetermined criteria. These criteria can be defined by:

- **The vendor:** in this case, the claims given by the vendor are verified, without technology approval or endorsement. This option is called 'claims verification' in ETV Canada
- **The buyers, stakeholders, etc.:** the minimum performance criteria can be defined to allow comparison with best performing products as a reference

The project will develop such a system for innovative site-characterisation- and monitoring technologies and also evaluate whether it can be transferred to site remediation technologies. It includes a test-phase, demonstrating the draft ETV-system by the project participants and organising an open call for participation in a first round of the ETV-system application. A strong impact of PROMOTE is expected to be a faster market introduction of novel techniques, hence strengthening the competitiveness of technology developers in Europe. PROMOTE has the potential to act as the precursor of a pre-normative verification system, overcoming implementation barriers and bridging the gap between innovative and standardised techniques.

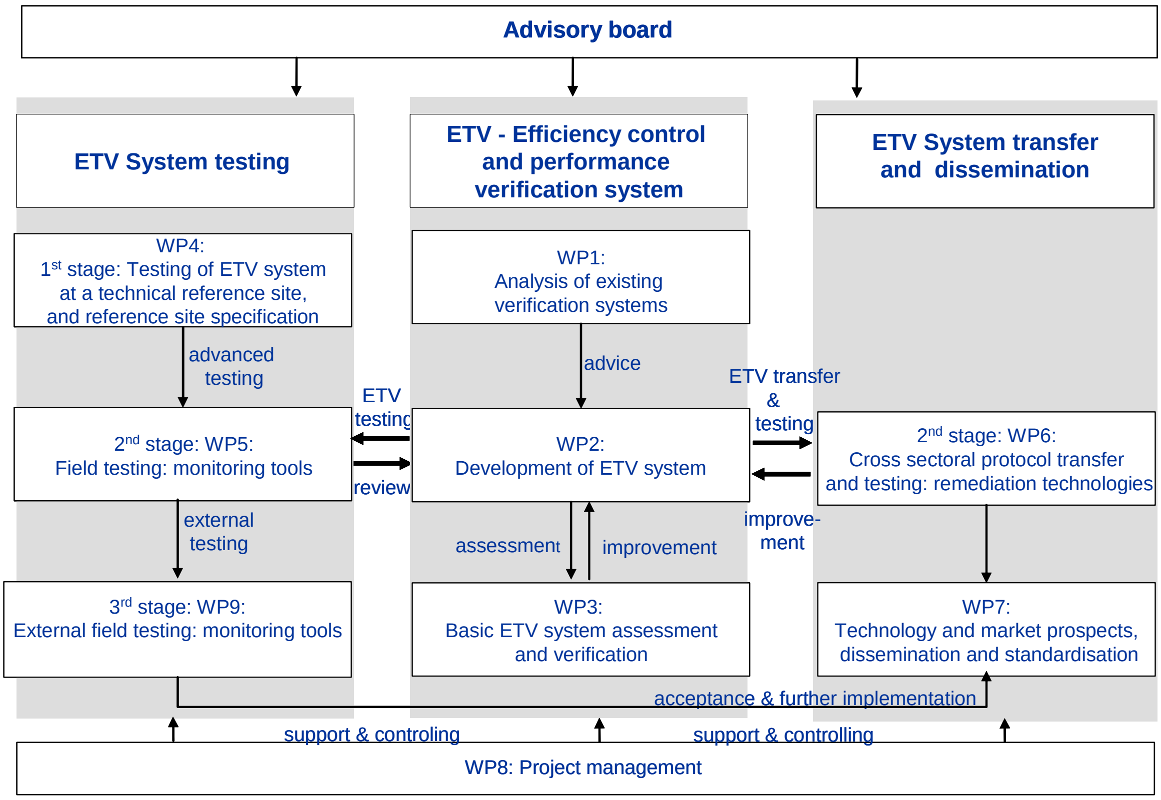

Figure 6 Schematic diagram of the PROMOTE project

The first phase of the project includes the following activities:

- An overview of existing approaches for validation/verification and actual strategies to develop ETV systems;
- Identification of common elements of validation/verification system for different Member States;
- Identification of non-technical aspects (e.g. roles stakeholders, economics, relation to existing standardisation and QC-procedures);
- Assessment and guidance for information needs, criteria and conditions to be fulfilled in development of the system
- An elaboration of the draft ETV scheme

From the work to date, the consortium meetings, questionnaires and lessons learned elsewhere the following elements emerged that will have to be adequately addressed before a European equivalent of the ETV can be instigated. The system should be organised at a European level; sufficient time, as well as money, should be allowed to complete the verification process for a technology and additional public and private money would be necessary for the development of verification protocols, verification studies and the continuity of the system. It is also clear that vendors would not be the only group who would be the initiators of verifications. US and Canadian experience shows that stakeholder groups, like authorities or industry representatives also can be interested in new technology. Multiple points of entry would strengthen the support of the ETV-system by allowing it to be driven by groups other than vendors. A multi-stakeholder perspective would also be necessary to give the system the status it needs to become widely accepted. For example the acceptance of data and recognition of an ETV-logo by authorities is an essential element of the decision to buy innovative technologies. Stakeholders want clear and defendable data that can be presented to the authorities, through a permitting process for example.

As the aim is to improve innovation, on-site verification is an essential part of the process, therefore in subsequent phases the draft scheme will be evaluated by performing a field verification study at a test site in Poland, where testing of a variety of technologies is already underway. Examples include a sensor array for volatile organic compounds in the unsaturated zone (in a direct push cone), a fibre optic photometer for dissolved PAH & BTEX in groundwater (in a direct push cone), a photometer for dissolved Phenols, DOC, and Electron acceptors, and active and passive multilevel groundwater sampling systems. Other steps include the development of a system for the transfer of ETV to related environmental technologies in cooperation with related EU projects and the setting–up a "CEN Workshop" procedure to come to a common understanding of verification requirements

The work of PROMOTE is closely linked to the interests of NICOLE in several ways. NICOLE covers the identification and management of industrially contaminated land from the perspective of landholders. NICOLE can act as one of the platforms which is used to share and exchange knowledge on the development of the EETV. It could also be a source of input for the identification of stakeholder requirements. Innovative technologies that could benefit from verification could be suggested in a multi-stakeholder setting. A further valuable link between the two would be the potential for the NICOLE network to be a source for the identification of testing sites for (future) verifications: the proposed Site Characterisation and Monitoring working group may also be able to contribute its expertise to the development of an EETV.

Overview of technologies for chemistry and sampling *Tim Hart, Cybersense Biosystems, UK*

Field analysis is an important tool in both site characterisation and the subsequent development of remediation strategies. It reduces uncertainty associated with contaminant heterogeneity and manages errors associated with sampling. It also provides a potential opportunity to save significant amounts of project time, while at the same time reducing costs and producing a management strategy which is more defensible, being based on field analysis. A variety of portable instruments and test kits are available to measure the nature, quantities and spread of contamination in the field in real-time: they have the advantages of speed, high throughput and a relatively low cost per sample. When used in conjunction with more rigorous laboratory analytical methods in a well designed sampling strategy, the combined data set allows robust planning and strategic decisions to be made on the basis of reliable data at relatively low cost (Figure 7).

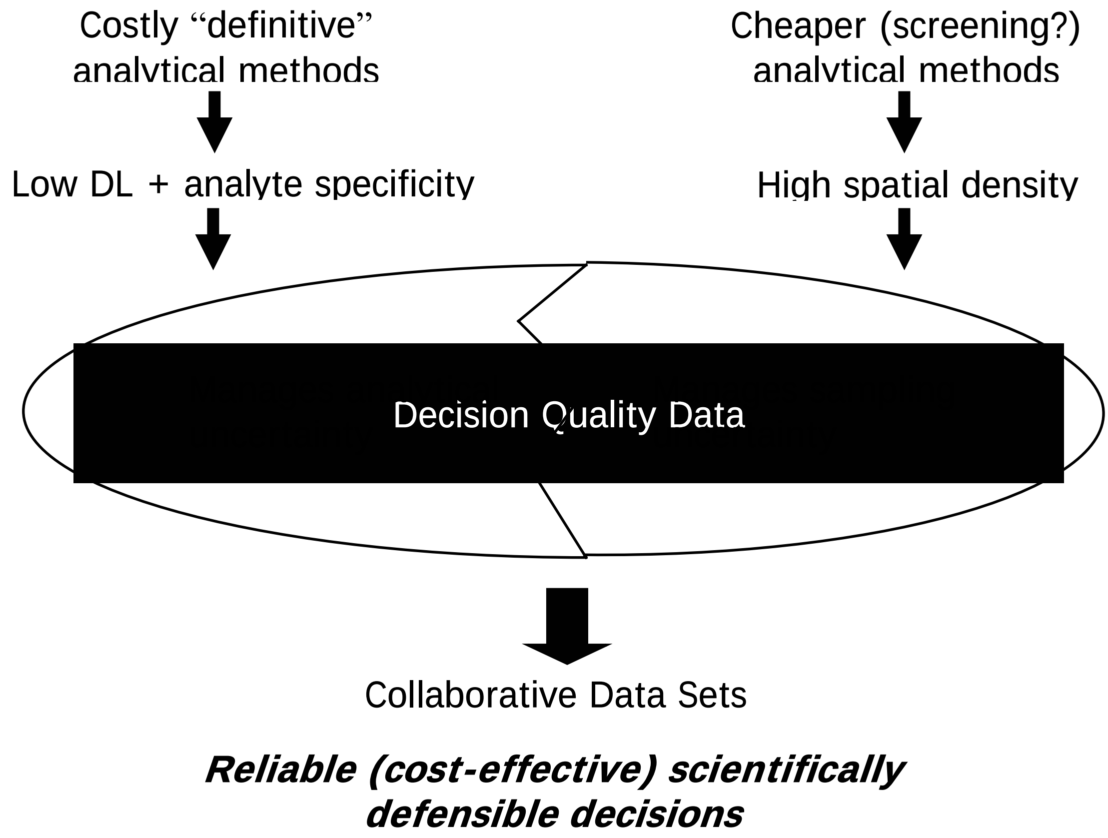

Figure 7 Field analysis: an integrated Data Solution

A range of field analytical tools are available to measure the wide variety of organic and inorganic substances which are potentially of interest to those investigating contaminated land. Each tool is suitable for measuring either an individual substance or a range of substances in the field and each has advantages and disadvantages. In the case of organic materials for example, a range of chemical test kits are available; they are generally easy to use and provide rapid results, although these results may only be qualitative and may suffer from interference, which affects the quality of the data. Immunoassay tests are available for a variety of compounds and provide very sensitive data (~0.1 ppm); however, they are less easy to use than chemical kits and may overestimate values. UV fluorescence allows easy measurement of TPH, PAH and PCB at a low cost but the available measurement window is often too small, while electrochemical techniques are the only (low cost) ones which can be used to measure chlorinated solvents in the field. PID measures volatile hydrocarbons by gas analysis and is quick and easy to use, but has interference and calibration issues. Portable GC/MS is commonly used for the analysis of semi-volatile organics as it is both highly specific and sensitive; however, it is expensive and requires training in its use and good quality control needs to be employed. The final methods for measuring organic materials are *in situ* probes such as MIP and ROST, which provide good quality *in situ* data but it is only qualitative.

Inorganic substances in contaminated sites can be measured by portable XRF, with same advantages and disadvantages as when used for organic substances (speed versus interference and limits of detection). Colorimetric kits are easy to use and can be applied to a wide range of substances, but they may suffer from interference and bias. Toxicity tests, for example a bacterial bioluminescence total (acute) toxicity test, provide an estimate of the total contaminant burden and detect the widest range of contaminants. It is an easy, rapid and auditable technique but it has problems with the available limit of detection.

Important methodological issues of using both field and laboratory data include the need integrate and manage data, the potential to make decisions based on field data and the quantification of errors. The presentation outlined CyPlans™, a tool designed to assess the technical and economic value of using field analytics within projects and facilitates the integration of field and laboratory data. The tool could be used to derive data quality objectives, develop decision rules and demonstrate the applicability of a method in particular applications. An on-site data management tool (DUMATTM), which can be used to manage field and laboratory data together was also described. It allows decisions to be taken with field tool data using a pre-defined level of confidence; it takes both fixed lab and field data and estimates all measurement errors and can be continuously updated as a project proceeds improving accuracy. It is the first commercially available tool to allow project-specific management of laboratory and field data uncertainty.

Sampling issues, in particular the influence they have on data quality and reliability were also discussed. Sample size, particle size and the behaviour of individual contaminants in the soil were all cited as important points to consider in assessing data quality and designing sampling and analytical programmes, concluding that the Minimum Economic Value can be the main driver of sampling frequency. Final thoughts on the issue were that data quality underpins everything we do and that laboratory data on its own is insufficient to make an informed decision: field analysis helps to reduce uncertainty in contaminated land assessment and make land management decisions more reliable at relatively low cost. However, for such an approach to be successful the field data must be of high quality and appropriate to the problem being assessed, it must be considered from the outset as an integral part of the assessment; data quality is essential to making good decisions.

Cost- and time-efficient site assessment: two case studies using an interdisciplinary approach *Thomas Gebel, Clayton, Germany*

A theoretical approach to site assessment developed through the NORISC[18] project of the fifth framework programme and its subsequent application in two field sites was described. This new approach is interdisciplinary. It differs from conventional site assessment in that, following an historical investigation, the site investigation, risk-assessment and remediation plan undertaken in a conventional approach are replaced by a single, all inclusive, interdisciplinary process. As in the conventional approach, this is followed by remediation and revitalisation and investment (see Figure 8).

The investigation had several objectives, including:

- testing the on-site methodology in practice;
- developing interdisciplinary teamwork between different sciences in the field of contaminated land investigation;
- developing and verification of a flexible investigation scheme;
- testing of analytical techniques that could be brought on-site;
- adapting and refining of the site model to match the demands of stakeholders;
- reporting of the investigation results and the evaluation of data

Two sites were selected to test the approach. The first was a packaging, paint and print shop in Lauterecken, Germany. The site was 2.5 hectares in size and was contaminated with TPH, BTEX and CHC. A 3 day site investigation was undertaken in August 2004 to measure soil and soil gas. The second site was in Budapest, Hungary; a ten hectare site used for fuel storage and electrical components that was contaminated by TPH, BTEX, CHC and heavy metals. The investigation lasted for five days and investigated soil and groundwater. The methods employed to investigate the sites are listed (by contaminant) in Table 3.

[18] Network Oriented Risk assessment by In-situ Screening of Contaminated sites

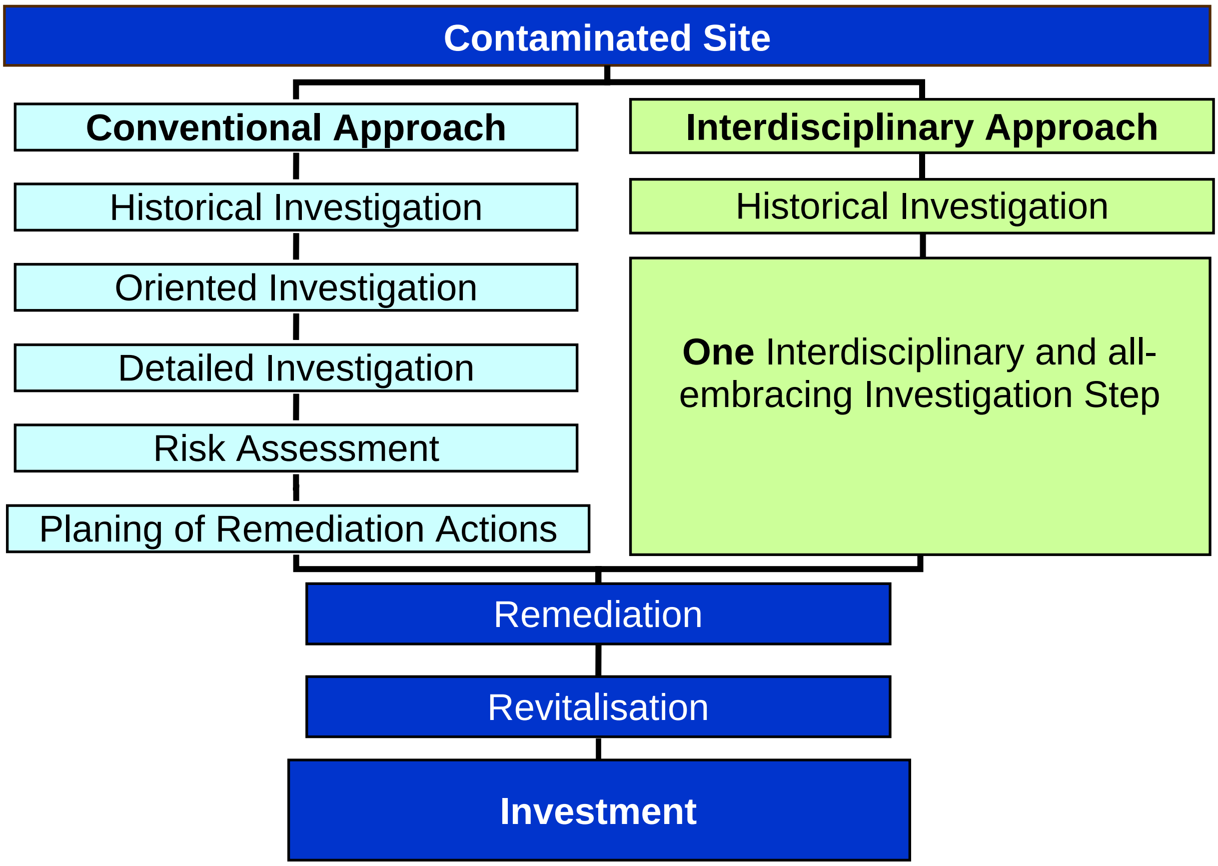

Figure 8 Comparison of a Conventional Approach against an Interdisciplinary Approach

The results of the Hungarian investigation into hydrogeological testing and on-site visualisation of the contaminant plume and a subsequent risk assessment in Hungary demonstrated that an assumption of a continuous clay layer separating two Aquifer systems that had been made during a conventional site investigation was wrong. By using geophysics it was shown that contaminants could flow unhindered through the permeable sands, saving significant time and money in comparison with the alternative of conventional drilling. It is estimated that the cost saving against a conventional approach was approximately €35,000.

Table 3 Methods used in the site investigations

Contaminant	Investigated Media	Analytical Tool	Model	Producer
Heavy Metals	Soil	XRF	Spectrum analyser 7000er series	Niton
BTEX	Soil water/soilgas	GC/TCD	3000 micro GC	Agilent Technologies
TPH	Soil	Infrared photometer	Petroleum hydrocarbon analyser TPH plus	General Analytics Corporation
TPH	Water	GC/FID	HP 5890 GC	Agilent Technologies
TPH	Soil/water	UV fluorescence	TD-500	Turner Designs Inc.

At the Lauterecken site, 54 Drillings of 50 mm diameter were made around the site: in each case 12 BTEX/CHC analyses in Soil Gas, 13 TPH analyses in Soil and 5 BTEX/CHC analyses in Soil were performed. The field investigations were conducted over 3 days during a weekend, resulting in no inhibitions of production. The cost saving against using conventional methods in this case was €8,600. In terms of data quality, on-site analysis delivers better results, because of its flexibility. More samples can increase the robustness of the assessment and it is possible to adapt the approach as circumstances dictate, giving the method more flexibility. The method allows fast correlation of sampling and analytical data and reduces costs through reductions in time and laboratory analysis. The use of geophysics offers advantages over conventional drilling by providing a 3-D view of the subsurface without the need for interpolation, making the identification of subsurface features easier, quicker and more accurate. There are several imitations to the technique; it cannot be used on very small sites, it is not suited to all contaminants or mixtures of contaminants, it requires highly qualified personnel, the limits of the analytical equipment mean that they may not be able to identify threshold concentrations and the techniques as a whole is less likely to be acceptable to regulators. The quality of the data derived should be judged according to fitness for purpose: if it fulfils the purpose required of it by the site investigator, it is good data, provided that the data themselves are reliable. The more complex the sample matrix is, the larger the bias in results can potentially be: the issue of the combination of sampling uncertainties and analytical uncertainties resulting in uncertainty over the results must be considered and attempts to reduce the impact of the problem must be undertaken. Only excellent and detailed project planning and management ensures the success of a combined investigation, as such a method lacks a second or third investigation step, which provides the opportunity to obtain additional data identified as a priority during the investigation.

Recommendations for integrated operation in the field based on the experience from the two site investigations are as follows. The use of on-site techniques and on-site decisions requires the best educated and experienced personnel and quality management in the field (chemists, toxicologists, geophysicists, hydrogeologists, environmental engineers are needed on-site and not in the Office or the Laboratory). Daily discussions between the different scientific disciplines being used on site are vital for smooth running of the investigation and gaining added value from seeing the combined results, which should be visualised daily to monitor progress. The daily planning should be flexible and adaptable, depending on the daily results and management of the project should be in the form of a network of experts with a central project manager.

Sorbisense passive sampler: environmental monitoring in groundwater and surface water *Hubert de Jonge, Sorbisense, Denmark*

Sorbisense is a Danish-based technology company, a spin-off from the Danish Institute of Agricultural Sciences. Sorbisense manufactures and markets passive sampling devices for environmental applications. It is currently involved in monitoring projects in Denmark and the Netherlands, monitoring organics, nitrate, and phosphate in groundwater and drain water. Some examples of the case studies were provided in the presentation to illustrate the value of the sampling device.

Using conventional water sampling and subsequent extraction/analysis methods (such as HLPC or GC) only provides a periodic snapshot of the chemical status of the water. By contrast, a passive sampler installed in the field, for example in a groundwater well, collects a cumulative sample over a set period specified by the client. Once removed from the site, the sampling cartridge is transported to the laboratory, extracted, and analysed using standard methods. The design of the sampling cartridge is porous and permeable to water and contains an adsorbent and a tracer compound. Once placed in-situ the cell is brought into capillary contact with surrounding water, a dissolved mass of solutes is adsorbed and the tracer leaches in proportion to water volume; the ratio M/V gives the average solute concentration during the installation period.

Three case studies were presented. The first was from a surface stream in the Aarhus district of Denmark. Concentration of nitrate and phosphorus were taken for a cumulative period of 14 days. The sample showed a 1:1 correlation with water samples taken during the period. A second case study was from an agricultural site in Denmark measured average nitrate and phosphorus concentrations in a groundwater well. The time-averaged concentration data provided a cost-saving to the site owner in comparison to an equivalent spot sampling strategy. Further, ongoing studies in collaboration with consultants, industry, laboratory and university groups were presented. These studies aim to measure solutes such as chlorinated solvents, creosol and phenolic compounds, BTEX and pesticides in groundwater. Among other, a project is conducted at a Copenhagen waterworks, monitoring trichloroethylene in goundwater. There were no public available data at this stage but the case study illustrated the potentially wide range of substances it was possible to monitor.

In summary, the advantages of the Sorbisense sampler in site monitoring were that it provided time-volume averaged data to support decision making. It reduced the number of analyses and site visits and handling time and as a result it reduced costs. Finally the sampler was capable of measuring a wide variety of substances commonly measured in contaminated land investigations, which gave it valuable flexibility.

Gore Sorber Survey to delineate a shallow CHC-plume *Dirk Nuyens, ERM France*

At present most of the costs of contaminated land investigation are expended on sites which are impacted by (semi-) volatile organic compounds. A wide range of technologies are available to monitor such substances. These include:

- soil sampling, active soil gas sampling;
- GeoProbe;
- MIP-probing;
- monitoring well installations

When developing an accurate site conceptual model, several issues besides the technology employed may also be significant, for example:

- time and cost of labour;
- the invasiveness of sampling in potentially sensitive areas such as residential zones;
- cost effectiveness;
- timing of the programme

There is a need for fast, accurate and affordable evaluation tools to help in identifying the critical areas requiring more detailed soil, soil gas and groundwater sampling. Such evaluation tools would help to reduce the time, cost and impact of a site investigation whilst saving on costs and improving the quality of the resultant site conceptual model.

One possible evaluation tool is the GoreSorber®, a passive sampling device capable of deployment for between one and fourteen days. It uses a gore-tex membrane and a sorbent to allow passive sampling of soil gas. It provides high sensitivity results for a broad range of organic compounds at low concentrations (0.01 to 0.1μg depending on the substance) and it is easy to install into a pilot drill hole (approximately 10 minutes per sampler). The analytical data are provided in mass units and concentrations from which maps of chemical concentration can be generated from the data.

An example of an application of the Goresorber was provided. The requirement was to delineate a shallow CHC plume on an industrial site, located close to a residential area and transport links making conventional sampling difficult and expensive. A voluntary site investigation and subsequent remedial action were taken by the problem holder. Below ground the geology was a mixture of sand and silt with a clay layer ten metres below ground level. Shallow phreatic groundwater was present at 1.7

metres below ground level underneath the industrial area and 0.5 metres below the residential area. The groundwater was contaminated with TCE and its degradation compounds such as cis-DCE and vinyl chloride, supporting the case that natural attenuation was occurring.

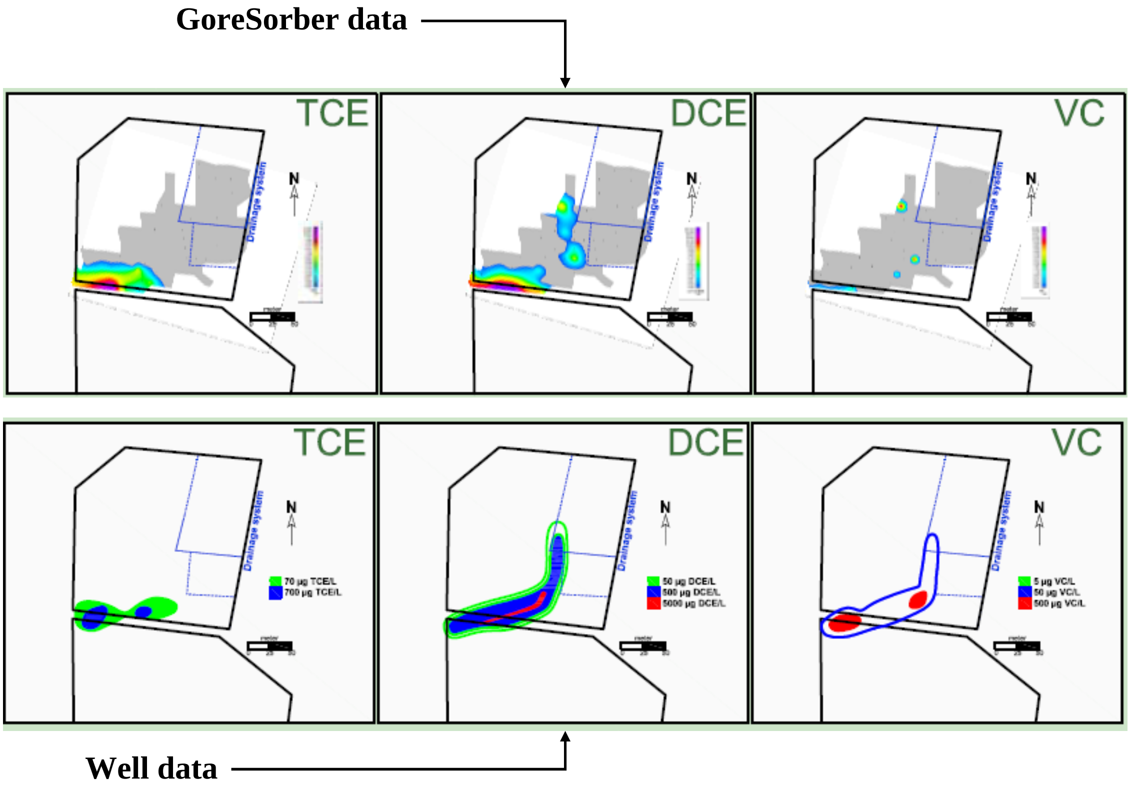

Figure 9 Comparison of GoreSorber and well data for the test site

The sampling regime consisted of installing 100 GoreSorber modules to a depth of 0.75 metres below ground level on a pre-defined grid at a spacing of between ten and twenty metres, a process which took two field technicians eight hours and allowed the sampling of a 40,000 m² area in a residential zone. The passive samplers were left in the site for two weeks before being removed, a process which also took eight hours. The samplers were then sent for testing in specialist laboratories in the USA. The total time needed for installation, sampling, analysis and data processing was four weeks.

The results of the GoreSorber survey confirmed the initial groundwater investigation data, showing a strong correlation between the groundwater data and the passive soil gas data. The on- and off-site plumes for all the CHC compounds were better identified by the additional data. The off-site migration information clearly deviates from the local groundwater flow data; an ‘unknown’ drainage system and limited, discontinuous dewatering have created this interference. On the basis of the GoreSorber data nine further monitoring well locations were installed to confirm the findings. The data from these wells confirmed the initial findings with the exception of vinyl chloride data for the drainage area (Figure 9). Both sampling tools demonstrate a depleting on-site source zone combined with a strongly attenuating off-site plume. The total cost of the investigation was €220 per sample.

The conclusions of the survey were that the GoreSorber data confirmed the initial groundwater data and the form of the downgradient CHC plume. It also detected interference on the groundwater flow pattern via a drainage system and local water extraction (crawl space dewatering). GoreSorber has proved to be a fast, cost-effective tool for the characterization and monitoring (both MNA & remediation) of sites affected by volatile organic compound pollution.

Innovative measurement techniques for environmental problems – new approaches and techniques *Norbert Klaas, VEGAS, Germany*

The work compared classical sampling design (i.e. a sampling grid, laboratory analysis, further, more precise measurements at a greater frequency to find the contamination followed by adjustment of the sampling grid on the basis of the available results) against new technology aimed at achieving results of comparable quality in less time at a lower cost.

In this case the new strategy involved the use of a standard range of field sensors to attain the detection of contaminants non-analytically (see Table 4). The aim was to design an easy-to-handle field system capable of providing data which would be available immediately on-site. Novel and traditional systems for monitoring soil, soil air and groundwater were compared. A groundwater well was also used for quality control.

The novel system had to be robust in order to withstand use in the field, yet remain practical for handling purposes; it had to provide data for various substances in soil, air and water at sufficient sensitivity (i.e. it had to provide data in the range of guide values for the different materials); finally, it had to provide the data on-line and it had to be affordable. With these criteria, the system designed was capable of measuring the chemical and physical parameters outlined in Table 4. The equipment was tested under laboratory conditions in tank nine metres long, nine metres deep and six metres wide, which was filled with graded sand material in distinct layers. A dense grid of sensors was installed at four levels in the tank, a total of 378 sampling points in an area of less than 500 cubic metres. An injection of TCE was made at a depth of 4.5 metres and the equipment successfully provided detailed soil gas and water data showing the spread of the contaminant at four levels within the tank.

The first of three field applications was located at a dry cleaning site. It was a conventional site assessment that allowed a field comparison between the traditional and the new technology. In some cases there was a significant discrepancy between the results derived from the different methods, sometimes a factor of between 10 and 100. Although very significant there are several possible explanations for this variability:

- comparison of an average measuring technique with a point measurement
- spatial variability between the two measuring points
- heterogeneity of the contamination across the site

Table 4 parameters measured and technology used

Parameters	Substances	Technology
Chemical	PAH	Fibreoptic systems
	CHC/BTEX	Fibreoptic systems
	NAPL	Optical sensor
	VOC #1	Gas sensor
	VOC #2	z.B. VOC sampler
Physical	Flow	Thermoflow
	Temperature	Thermoflow

In cases where there was no significant discrepancy, the concentrations were very low or below the limit of detection.

The Stürmlinger Sandgrube reclaimed landfill site was described as a second example of the application of the sensors for the measurement of on-site contamination by PAH. The results were then compared with groundwater well data.

A third potential application was the use of a photometer and a mobile laboratory to investigate a site to establish a remediation action plan. The photometer was designed to measure CHC, HC and PAH concentrations in soil and water and was designated to investigate a contamination plume to establish its forma and direction to determine the optimum location for monitoring wells. A rapid analysis of 24 temporary monitoring wells was undertaken; with each sample within each well taking 10-15 minutes, the whole operation was completed within two days. The results showed that a narrow plume had developed, extending beyond a nearby river and possibly being fed by a secondary source. Based on these data a series of four permanent groundwater monitoring wells were installed.

The conclusions of the work to date are that on-site analysis from such sensors is suitable for detecting and delineating contaminants in the sub-surface. It can only provide a semi-quantitative measurement of contamination, but the resolution afforded by more sampling points is beneficial for determining the design of further remediation monitoring. The first prototype sensors have been developed to monitor a variety of contaminants, including VOCs, NAPL and PAH. Their use has now been successfully demonstrated in both controlled laboratory conditions and field trials.

Conceptual site model validated by real time flow measurements and passive diffusion samplers *Marcel Kolle, NOCON, The Netherlands*

A conceptual model of groundwater flow and contamination was developed and validated using a field study. The study site was located in the western Netherlands, in an area characterized by complex lithology, where approximately ten dry/wet cleaning companies had been established over time. The client wished to redevelop a former dry cleaning site to establish a factory unit to let. At the time of the investigation the site could not be redeveloped due to DCE and VC contamination in groundwater at 35 metres depth. The site of the client was the most likely source of the contamination, given the receptor of pollution was immediately below the site and an alternative source of pollution, 120 metres away was out of line with the established regional groundwater flow. It was possible however that the regional groundwater flow model may have overlooked the possibility of a secondary flow which would link the alternative source to the receptor. A traditional survey identified a very shallow groundwater gradient (1.5cm) over the 120 metres between the client and the alternative pollution source; although this gradient could have been sufficient to alter flow in the direction of the site, a further investigation was undertaken. Due to restrictions on cost and accessibility a single well flow measurement was undertaken between the client’s site and the potential alternative source. A probe containing a camera system, which used a laser to highlight solutes and gauge groundwater flow from their movement, was used as a novel technology to measure groundwater flow. The new measurements confirmed the conceptual model of a detour from the regional groundwater flow, moving quicker than had been expected given the shallow gradient.

Having demonstrated the direction of groundwater flow, diffusion samplers were used at the site to determine any vertical delineation of contamination in the groundwater plume. If the conceptual model was correct the contamination would be deeper as it had been transported from the other site. However the vertical distribution of contamination showed that there was a two-tier contamination, with higher concentrations near the surface and lower concentrations below with a distinct boundary. This implied that there could be two sources, the client’s site and the alternative source.

The result of the investigation was that it was demonstrated that groundwater flow was moving in a different direction to the regional flow at a faster rate than forecast and there were two sources of contamination. The client received a building permit for the site without having to incur remediation costs. The survey cost approximately €5,000, which compares favourably with the cost of an equivalent deep well survey (€20,000) and also saved a considerable amount of time.

Closing session Wouter Gevaerts, ArcadisGedas, Belgium

The closing session of the conference posed the simple question 'What have we learned?' Important points highlighted in the presentation were that experience and the ability to learn from new situations were important assets when assessing the potential of innovative technology to resolve issues surrounding the development of a conceptual model which cannot be addressed by traditional methods. The use of such innovative technology should be used appropriately rather than because they are available and should be verified and quality controlled carefully to support their use. The prudent use of new technologies will also allow more accurate, more insightful conceptual site models which could in turn improve site investigation and ultimately reduce the cost of site investigation. In this way it may be possible to achieve quality case studies employing new technologies which help both to promote their further use.

3 Discussion

This section (and the concluding remarks) are drawn from workshop questions and answers, the closing session and further comments kindly submitted by delegates following the workshop.

A wide range of innovative, pioneering technologies and applications in site assessment were presented at the workshop. NICOLE members at the workshop had a strong interest in developing new, more efficient methods of site investigation and that site characterisation and monitoring are seen to be important and interesting topics. This interest has continued since the Pisa workshop on cost-effective site characterisation in 2002.

The most successful applications of new technologies were those linked to supplying data for a conceptual site model, for example studies which used new technology to elaborate a CSM or those which used novel technology where access using traditional methods was impractical due to logistics and expense. Presenters describing technologies without clear reference to a site conceptual model were less successful in demonstrating the value of the technology employed: in many cases the major advantage of the technique in this context was to provide a cost saving rather than providing an improvement in the understanding of the site (i.e. that it offered something to the site investigation that conventional technology could not provide). It should be emphasised that the ability to provide information at a reduced cost should not be dismissed as unimportant, as it could affect the viability of a whole site investigation project, thus the emphasis on the speed, efficiency and cost effectiveness of various technologies was unquestionably valuable.

Most of the questions raised were technical, fewer related to the application of the technology or the wider impacts of their potential adoption at a wider scale. Some of the presentations at the meeting explicitly discussed the application, and best strategy for using, innovative site characterisation, in the context of the conceptual site model. Presentations tended to focus on the detail of techniques and their cost and other advantages compared with other techniques rather than on the context of the techniques within an overall information strategy. However, a clear message did emerge about the comparative value and reliability of passive sampling and flux monitoring in comparison with more traditional concentration monitoring.

One suggestion that emerged from the Carcassonne meeting was that a workshop (or NICOLE project) looking explicitly at the process of selection of technologies, that discusses the barriers to the uptake of innovative technologies could be very useful.. It was clear from the meeting that the use of appropriate technology is essential to successful and cost-effective site investigation and monitoring. However, the selection mechanism and criteria and the technological information that industry can use are lacking at this stage. The development of guidelines for the appropriate use of technology would be a major step forward in the adoption of, or willingness to adopt new technology on a large scale. In order to achieve this, emerging technologies need to be evaluated more thoroughly; they must also be capable of being evaluated independently.

Despite the impressive results demonstrated at a trial or experimental scale in many presentations, their use on a wider scale appears limited, and there appear to be few objective comparisons of emerging techniques with each other or with established technologies. This was highlighted as a key barrier that prevents wider-scale adoption and, most importantly from an industrial company perspective, their approval by regulatory authorities. Regulatory approval is of vital importance to industrially contaminated land as industry is unlikely to take financial risks in adopting a new field measurement or analysis technology if the data from that technology will be rejected by regulators. This is a similar situation to the lack of an EU technology verification scheme for remediation technologies, a gap that is being addressed by a number of EU initiatives such as the PROMOTE project that was presented at this workshop. Therefore more emphasis needs to be placed on understanding and defining the barriers that prevent wide scale uptake of such technologies and the advantages that such technologies possess over the *status quo*.

NICOLE as an organisation has been trying to promote the development of an appropriate framework for the adoption of new technology, where it was appropriate to do so: two workshops have been conducted on themes relevant to this issue (Budapest and Barcelona). However, some concerns were expressed in post-meeting comments that there seemed to have been little change in the use of technology since the NICOLE Pisa workshop in 2002. Perhaps it is timely to support the development of “mechanisms” to move technology from the theoretical development stage, through the pioneering study stage to acceptance on an industry-wide scale, for example provision of guidance. From the current position several possible courses of action could be pursued, either by NICOLE or with the support of NICOLE:

- Initiate dialogue with industry and regulatory bodies with a view to developing a framework for technology testing and approval
- Support an effective monitoring and testing programme for new technologies that is widely accepted by all interested parties
- Support the development of monitoring guidelines for the comparison of technologies so that appropriate technology can be selected on a fitness for purpose and cost-effectiveness basis
- Emphasise the importance not only of improved data quality (in terms of cost, speed and ease of use) but also of improved use of data in terms of developing good quality site conceptual models
- Support training in and dissemination of advances in site characterisation techniques amongst service providers and regulators.

Industry is unlikely to invest in the use of new and innovative investigation technologies, even if such methods have the potential to produce improved site conceptual understanding, unless the performance characteristics and cost-benefit of the technologies has been independently verified and the data produced by the methods is going to be accepted by the regulatory authorities. By moving the situation from one of technology push-led innovation and opportunism it may be possible to achieve a smoother, more widespread adoption of innovative, effective, appropriate technologies.

It is very important that the users of new techniques and their clients are involved at an early stage in any development of programmes to verify or validate new site characterisation tools. If this consultation is left too late it will not be effective, and will lead to a project of less influence. NICOLE is an important opportunity for the developers of these proposals to converse with both their market place (service providers) and site owners (industry). Equally, regulators and those involved with policy also need to be involved from the earliest stages of project development, as a validation/ verification project that is not favoured by regulators is of little interest to service providers or industry. An inclusive approach that improves dialogue between developers, users, their clients and regulators would lead to a more efficient adoption of innovative site characterisation technologies where they could be shown to be cost-effective, appropriate and able to meet the needs of environmental protection regulations.

4 Concluding Remarks

In general the meeting, the field excursion and the presentations were very well received; the issues raised by the meeting related as much to what had not been presented as to the wide range of technologies and applications illustrated. It was clear from these presentations that the chief driver for the innovative site characterisation techniques presented at this workshop is clearly cost reduction compared to existing technologies rather than improving site conceptual models. Such savings should not be dismissed as unimportant or insignificant.

It is apparent that there is a clear gap in knowledge concerning how to select the most appropriate technology. However, it was clear both from the meeting and subsequent comments that the use of appropriate technology is essential to successful and cost-effective site investigation and monitoring, despite the fact that an appropriate selection mechanism that industry can use is not available at present. To achieve this, emerging technologies may need to be compared in the context of a verification project or programme, in a similar manner to the independent remediation technology verification protocols that are being developed by EU projects such as PROMOTE. Despite the possible opportunities for more effective site characterisation that seem possible, in some presentations the extent of use and the degree of acceptability to regulatory authorities was not immediately apparent. Understanding and defining the barriers that prevent wide scale uptake of such technologies and the advantages that they possess, along with guidelines for the appropriate use of such technology would be a significant assistance in its adoption on a large scale.

It was suggested that improved dialogue between consultants, researchers, industry and regulators regarding a mechanism to move technology from development through to acceptance on an industry-wide scale would be a vital step in any process aimed at evaluating new technology.

Annex 1 List of Participants

Initials	Family name	Organisation	Country
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R.	Busink	Corus Steel BV	NL
L.	Buvé	UMICORE	Belgium
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S.	Capus	Administration de l'Environnement	Luxembourg
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J.L.	Crabos	APESA Association Pole Environnement Sud-Aquitain	France
J.	De Fraye	MWH	Belgium
H.	de Jonge	Sorbisense ApS	Denmark
G.	Deslauriers	Umicore France	France
L.	Diels	VITO - Flemish Institute for Technological Resarch	Belgium
P.	Dietrich	Centre for Environmental Research (UFZ) Leipzig-Halle	Germany
P.	Dosoudil	Dekonta, comp	Czech Republic
C.	Egelstig	JM AB	Sweden
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Th.	Gebel	Clayton Umweltschutz GmbH	Germany
W.	Gevaerts	Arcadis Gedas NV	België
O.	Gosset	Gaz de France	France
J.C.	Gourry	BRGM	France
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M.	Henssen	Bioclear BV	NL
M.E.	Hilwig	Hofstede Advies	NL
N.	Hoekstra	TNO Built Environment and Geosciences	NL
W.K.	Hoitzing	DHV Environment and Infrastructure BV	NL
N.	Hoogeveen	DHV	NL
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I.	Iribarren	Spanish Geological Survey	Spain
P.	Jacquemin	ADEME Midi Pyrénées	France
R.	Jacquet	Solvay S.A.	Belgium
C.W.F.	Jansonius	Arcadis	NL
P.	Janssens	Tauw NV	Belgium
G.	Kayens	OVAM	Belgium
Th.	Keijzer	Tauw bv	NL
N.	Klaas	VEGAS Research Facility for Subsurface Remediation	Germany
M.	Kolle	Nocon BV	NL
H.-P.	Koschitzky	University Stuttgart	Germany
L.	Lentzen	ATM BV	NL
A.	Liljemark	Sweco Viak	Sweden
V.	Luberti	Dow Italia Srl	Italy
J.	Mallach	MediTerra Consultors Ambientals, S.L.	Spain
G.	Marceau	ICF Environnement	France
V.	Martí	Centre Tecnológic de Manresa	Spain
C.	Mattalia	ENVIARS & Partners	Italy
S.	McKenna	Corus UK	UK
V.	Musil	Dekonta a.s.	Czech Republic
P.	Nielsen	MediTerra Consultors Ambientals, S.L.	Spain
D.	Nuyens	ERM France	France
J.	Palte	Eurofins-Analytico	NL
B.	Palumbo-Roe	British Geological Survey	UK
F.	Perie	TOTAL Petrochemicals France	France
J.	Pletnicka	Technical University	Czech Republic
M.	Polenka	GEOtest Brno, a.s.	Czech Republic
A.	Polenková	GEOtest Brno, a.s.	Czech Republic
U.	Puppini	ESI Italia Srl	Italy
A.	Reed	Shell Global Solutions	UK
F.	Richter	Dow Olefinverbund GmbH	Germany
V.Y.	Rudneva	International Science and Technology Center (ISTC)	Russian Federation
G.	Scarpa	Dow Poliuretani Italia Srl	Italy
A.J.M.	Schelwald-van der Kley	Port of Rotterdam / NICOLE ISG	NL
F.	Seco Olivella	Centre Tecnológic de Manresa	Spain
J.-L.	Sévêque	Sévêque Environnement	France
A.J.C.	Sinke	BP International	UK
R.	Sisto	Enitecnologie S.p.A.	Italy
R.F.P.	Spijkerman	Oranjewoud BV	NL
J.	Strandberg	Swedish Environmental Research Institute Ltd.	Sweden
M.	Sumann	Ecoappraisal	Italy

K.	Taggart	Dow Southern Africa Pty (Ltd)	South Africa
A.F.A.	Thijs	Shell International Chemicals BV	NL
D.	Trivedi	BNFL Group	UK
R.P.L.	van Eijsden	Eurodems BV	NL
K.	van Geert	Arcadis Gedas	Belgium
C.C.D.F.	van Ree	GeoDelft	NL
P.	van Riet	Dow Benelux BV	NL
E.	Vaszita	Budapest University of Technology and Economics	Hungary
J.J.	Vegter	Common Forum	NL
K.	Visser	SigmaKalon	NL
E.P.C.	Visser-Westerweele	Visser-Westerweele Milieuadvies	NL
J.	Waters	ERM	UK
H.	Weiss	Umweltforschungszentrum Leipzig-Halle	Germany
B.J.	Wilton	URS Netherlands BV	NL
R.	Wolbrink	Royal Haskoning	NL
M.	Zahnašová	Technical University	Czech Republic
I.	Zdanevitch	INERIS	France

Annex 2 Summary of the site visit to La Combe du Saut (Salsigne)

Overview presentation of the remediation of the former mining site at La Combe du Saut (Salsigne) *Patrick Jacquemin, ADEME Languedoc Roussillon, France*

The[19] Salsigne gold mine was established in the mountains to the north of Carcassonne and operated for the majority of the 20th century. Ore extracted at the site was transported to a by train to a processing plant at La Combe du Saut. During the 20th century approximately 15 million tonnes of ore were extracted to produce approximately 100 tonnes of gold. A characteristic of the ore processed at the site was its high content of arsenic pyrite, which was converted to arsenic trioxide during the smelting process. Over time large quantities of highly contaminated mine wastes were deposited in the vicinity of the processing plant, resulting in a legacy of soil and water contamination and (once the mine and processing plant closed in 1992) a derelict industrial facility. Since closing the mine site has been in the hands of a consortium of land remediation and operating companies, which have worked together to remediate the site effectively from 1999 up to an anticipated completion time of late 2006. The project has been a Diffuse Pollution from Mining Activities (Difpolmine) demonstration project and has involved co-operation with IRH Environment, Hasselt University, Budapest University and the French Water Agency RMC.

In 1999 at the start of the remediation project, the most significant problems found at the site were contamination of the watercourse by arsenic and the large quantity of residual arsenic contamination in the waste material on site; thus the two key aims of the remediation were water treatment and containment of pollutants.

The initial characterisation of the site prior to any remediation identified 2.4 million cubic metres of waste and contaminated soil which required removal. Concentrations of arsenic in this material revealed concentrations up to 100,000 mg/kg, far in excess of any risk threshold and impossible to clean to a safe level. This material was therefore best treated by containment rather then improvement. Monitoring of runoff at the site indicated that most arsenic was lost via this route in particulate form. Significant quantities of material could be lost through water erosion as the region can be subject to intense rainfall (the heaviest rainfall event on record occurred in 1999 and a further significant event (return period >100 years) occurred in 2005). A further significant route for arsenic transfer was the dispersal of dust via the wind in the dry summer period, although this contributed a far smaller quantity of the total arsenic loss than that lost through water transfers. An estimate of the total annual arsenic transfer showed that of 1,900kg lost per year only 60kg was accounted for by dust, the remainder being transferred via groundwater, runoff and infiltration.

The conceptual model of risk therefore identified two pathways by which arsenic posed a risk to human health. Firstly via the inhalation, ingestion or dermal contact with arsenic laden dust and secondly via the ingestion of contaminated water or foodstuffs contaminated by water (fish and irrigated fruit for example). The remediation work therefore concentrated on the removal of these pathways by excavating the core sources of pollution. The most polluted material would be contained on site and capped and revegetated, thereby removing the link to the human population and the environment, while the excavated areas (which had to have a residual contamination of <3,000 mg/kg As) were to be controlled by phytostabilisation and water management, reducing the possibility of arsenic transfer off-site.

The timetable of remediation was as follows:

- **1999-2000:** Removal and storage of hazardous material within the buildings on-site

[19] This introductory presentation was given at the workshop venue

- **2001:** Demolition of buildings on-site
- **2002:** Construction of a watertight area on-site for the containment of hazardous material from the site
- **2003:** Completion of site demolition
- **2004:** End of the construction of the watertight area
- **2005:** Excavation of waste and contaminated soil and transportation to the containment area (on-site)
- **2006:** Capping of the waste material

Once remediation activity is completed the site will be completely vegetated and landscaped. Ongoing monitoring at the site will assess the success of the remediation project. There is no planned onward use for the site due to the high levels of residual contamination; the project has merely aimed to reduce the impact of the site on the wider environment. The total cost of the project is estimated at 12.5 million euros, thus it can be seen that risk management of sites with metal contamination is highly costly when the site is both highly polluted and highly extensive

Presentations at La Combe du Saut (Salsigne)

Following the presentation on the remediation work being undertaken at La Combe du Saut, delegates were taken to visit the site itself, a short distance from Carcassonne. The principal problem associated with the site was a high level of contamination, particularly arsenic. As a result there was a large quantity of contaminated soil and waste material on-site and the contamination of local water was a significant issue. The site visit consisted of a series of presentations at four locations within the site, demonstrating a variety of investigative and remediation technologies which have been employed during the programme. These presentations were given by researchers who are or who have been conducting the work. The presentations are briefly summarised below:

A run off water treatment plant, the water management system and the full scale follow up programme

The first site of the tour outlined study work to investigate the chemical quality of runoff from the site. The aims of this work were threefold: to know how much pollution of what type was reaching the river via runoff; to identify who is responsible for the pollution and to understand the pollution transfer processes operating at the site in order to design an effective solution.

Data for the monitoring period (which included the heaviest rainfall event ever recorded at the site in 1999) showed that a several trace elements (As, Cu, Cd, Pb and Zn) as well as cyanide were present in significant concentrations. Data for arsenic ranged in concentration from 2-40 mg/l. The majority of the arsenic pollution (80% on average) was in particulate form; there was a significant correlation between the concentration of arsenic in the sediment and the concentration in water.

These data have allowed the development of a conceptual model of arsenic transfer for the site. There are two distinct sources of arsenic, namely primary solid sources such as the ore itself and arsenic trioxide in debris from the smelting process and diffuse sources caused by spillages during the operation of the site. Due to processes of erosion and chemical transformation the arsenic is transferred to the watercourse in both particulate and dissolved form.

Two forms of water management system were described. In the first case a series of drainage channels were developed around the site from both existing drainage and created channels as the form of the site was altered. The channels were subsequently identified as ‘dirty’ or ‘clean’ depending on which parts of the site they drained and the two groups of channels were kept apart as far as possible and treated separately to reduce costs. Sand traps were installed to prevent major transfer of arsenic and the water was diverted to a treatment plant on-site, where contaminated sediment was treated and removed. The second system treated runoff on-site up to a maximum flow rate of 200m3/h (a flow rate governed by the size of the system. Flow was diverted into a flume, into which a flocculant and a base material (to adsorb soluble arsenic) were added and mixed with the incoming water and agitating the flow. The water then transferred to a mixing well before being moved into a settling tank where the flocculant caused arsenic contaminated sediment to settle out and the cleaner water to pass back to the main flow system.

Niton XRF demonstration

The objective of this project was to assess the level of arsenic contamination across the site cheaply, quickly and with a good degree of accuracy. A large number of measurements were also required. The solution was to use a portable X-ray fluorescence device, capable of analysing fourteen elements *in situ* within a few seconds per measurement; depth of the measurements was between one and five millimetres. A GPS was also used to provide accurate sample location and the data were subsequently plotted using a GIS. The advantage of the system was that it was fast and non-destructive, allowing up to 150 measurements per day; this resulted in cost savings through reduced labour and laboratory time. The data from the device can be influenced by characteristics such as soil moisture and texture, therefore a series of laboratory analyses were conducted as a form of quality control. In the case of the study site the data showed a linear correlation, although such data would have to be produced for each site to ensure accuracy on each occasion.

Phytostabilisation studies

The aim of the phytostabilisation study was to assess whether such methods would be successful in containing pollution within the site, by reducing the amount of wind and soil erosion, runoff and percolation and reducing the mobility of pollutants. A series of greenhouse experiments to establish the potential for plant establishment in the soil and subsequent selection of appropriate plant species for the site were followed by plot-scale field trials.

A key problem to overcome in plant establishment was the development of a method to reduce the phytotoxicity of the soil, in particular due to the high level of arsenic. The solution employed was to add steel shot to the soil, mixing it into the soil to a depth of 30cm, which oxidises in the moist conditions to form iron oxide and manganese oxide, which immobilise arsenic (particularly anionic arsenic) as well as other metals; the effect of the steel shot has a long-term duration. Other improvers, such as lime, work well for cadmium and zinc but only have a short-term effect; in addition the resultant increase in pH increases arsenic mobility. The process of adding steel shot was tested initially in greenhouses using substrate from the site and beans as a test crop, demonstrating a notable reduction of phytotoxicity to a 'non-toxic' level. To select appropriate plants an inventory of species growing at the site was taken and those where seeds were commercially available were identified and germination tests were undertaken. Those which were successful also had to fulfil two other criteria, namely slow uptake of toxic elements to avoid contamination of the food chain and an ability to survive in soils of a low nutrient content; it would not be possible to add organic matter for fear of increasing contaminant mobility.

Having demonstrated that the method was viable and having selected the most appropriate plant species the experiment has now moved to the field plot scale, where treated and untreated plots, 5m x 20m in size were developed adjacent to each other at several points on-site. The plots were constructed to allow for sub surface drainage to be collected for monitoring to allow analysis of water flow and water and sediment quality. To date the treated plots have proved to be particularly effective at reducing arsenic concentrations in runoff following significant rainfall events

Completion of the confinement and the full scale phytostabilisation

The aim of this part of the site remediation was to design a containment system for the most contaminated material (>3,000ppm As) which could not be effectively treated. The programme, to be completed by the end of the year, involved the construction and dewatering of lagoons and the installation of a drainage system, the backfilling of the crater with 475,000m^3 of contaminated material and capping of the material with a bituminous geomembrane. The membrane was subsequently covered with calcareous material to a depth of 70 cm, which has been overlain with a layer of organic material from elsewhere on the site, which has been treated with steel shot as per the phytostabilisation study. Ultimately the area will also be established with vegetation, a process which will be informed by the field plot phytostabilisation studies.

Complex risk management at the Hungarian model site of the Difpolmine Project

The Difpolmine project also involves work at other sites and the final presentation offered a comparative study of an integrated risk assessment at the Toka mine site in Hungary, a former lead and tin mine, which aimed to assess the potential to adapt the risk management approach adopted at the Salsigne site to an area with both similar and different contamination issues. The Toka site includes pollution from both point and diffuse sources: the main contamination issue is the presence of cadmium and zinc in waste material soil, sediment and water, with runoff being the dominant pathway. An Integrated Risk Assessment was produced for the site and its surrounding catchment, identifying the key sources, pathways and receptors at a basin scale and presenting the information in a GIS format. Having used this risk assessment to identify the areas of highest risk from specific contamination and excavated and/or confined point sources of hazardous material a range of chemical and phytostabilisation methods will be developed to reduce the risk of water contaminated by metals leaving the site. A range of laboratory microcosm experiments are currently being undertaken to identify the most appropriate stabiliser. It has been possible to transfer much of the experience of the Salsigne remediation programme to a different site, but specific issues also need to be addressed.