Contaminated Land Research under the EU RTD Programme 'Environment and Sustainable Development'

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Abstract
The Fifth Framework Programme (5FP) is the principal 'vehicle' of the European Commission for the funding of research, technological development and demonstration projects. A call for proposals issued in 1999 within the Key Action 'Sustainable Management and Quality of Water' of the Environment and Sustainable Development Programme has led to the funding of 20 projects linking the contaminated land issue with the management of Europe's freshwater resources. A second call for proposals is scheduled for November 2000. This paper analyses the areas covered by projects from the first call and highlights specific research tasks which deserve further attention in order to achieve the targets of the 'Water Key Action' in particular in view of the upcoming call for proposals.

Keywords: Fifth Framework Programme, Concerted Action, Sustainable Management and Quality of Water, Water Key Action, NICOLE, CARACAS, BIOSET, CLARINET, CHAINET

INTRODUCTION

The European Research and Technical Development (RTD) Programme 'Environment and Sustainable Development' Programme is part of the 5th Framework Programme; its overall objectives can be summarised as follows:

- to support the implementation of EU Directives;
- to create a sound scientific basis for the preparation of new policies and legislation;
- to strengthen the competitiveness of Europe's industry – in particular small and medium sized enterprises (SMEs);
- to improve the quality of life and safety for European citizens;
- to ensure that development is sustainable.

Several Directives are relevant in the context of 'Contaminated Land – Management of Freshwater Resources', such as the Water Framework Directive, the Groundwater Directive, the Landfill Directive, etc. However, there is no European legislation addressing the problem of contaminated land. RTD work on contaminated land within the Key Action 'Sustainable management and quality of water' is therefore based on a critical analysis of national approaches within the EU Member States, the associated countries and the accession countries. It should support the harmonisation of regulatory approaches through the identification of best land use practices and the most sustainable management options for contaminated land and water.

Comprehensive information about the Fifth Framework Programme (1998 – 2002), its activities and calls for tenders and for proposals concerning the Specific Programmes is maintained on the CORDIS website (www.cordis.lu). As some of the projects, selected for funding on the basis of the next call for proposals, will lead within their active phase into the next main Framework Programme and into the European Research Area, it is advisable to read the respective existing orientation documents carefully. This is particularly important for the planning of co-ordination and networking activities.

THE FIFTH FRAMEWORK PROGRAMME AND CONTAMINATED LAND RESEARCH

The RTD programme 'Environment and Sustainable Development (ESD) covers four Key Actions:

1. Sustainable management and quality of water;
2. Global change, climate and biodiversity;
3. Sustainable marine ecosystems;
4. City of tomorrow and cultural heritage.

The ESD Programme also includes three RTD activities of generic nature:

1. counter-measures against major natural and technological hazards;
2. development of generic earth observation technologies;
3. socio-economic aspects of environmental change in the context of sustainable development.

Within these, the activities with greatest relevance to contaminated land are the following:

- from Key Action 1, *Sustainable management and quality of water,* under the Topic 1.4 *Pollution prevention*, Action Lines:
  - 1.4.1 *Abatement of water pollution from contaminated land, landfills and sediments*
  - 1.4.2 *Combating diffuse pollution*

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and under Topic 1.5, *Surveillance, early warning and communication systems*, Action Line:

1.5.1 *Pollution surveillance and control*

- from the Key Action *City of tomorrow and cultural heritage,* Action Line:

4.3.2 *Rehabilitation and reuse of brownfield sites.*

Action Lines refer to the Fifth Framework Programme documentation, available on the CORDIS website.

The implementation of the Programme under these Action Lines will be organised through one or more of the following tools:

- shared-cost RTD projects;
- thematic networks and Concerted Actions;
- programme-accompanying measures.

The relevant information on the call for proposals is being published in *Official Journal of the European Communities* and made available via the CORDIS website. The first call for proposals was announced in March 1999. It is planned to launch the second call relevant to the subject 'contaminated land/freshwater' on 15 November 2000 and this current call is outlined below.

Shared cost projects are either supported up to 50% of the full cost of the project (e.g. for industrial partners) by the EC, or up to 100% of the additional costs (e.g. for universities). Accounting criteria are strict and fully explained in the accompanying documentation. These criteria, and a tool to assist proposal writing (PROTOOL) are available from the CORDIS website. Basically, the programme 'Environment and Sustainable Development' is open to participation from countries from all over the world, however, financial EU support can be given only to organisations from the Member States, from associated countries and from accession countries. Details are listed in the respective information packages.

As well as RTD projects, the EC supports the implementation of the programme through 'Concerted Actions'. Concerted Actions are used, in particular, where the EC takes the view that the principal need is for the support of co-ordinating ongoing national activities together with the complementary EU RTD Actions. Furthermore, Concerted Actions can be used to identify the state of the art on a world-wide level and identify RTD priority areas where future research could offer a clear 'European added value'. Continuous monitoring of progress made in a certain area and dissemination of results and conclusions, leading to a more efficient problem-solving approach can be considered further essential elements of Concerted Actions. Information about support for the particular RTD problems of small and medium-sized enterprises (Exploratory Awards, CRAFT projects) can also be obtained via the CORDIS website. In addition, the CORDIS website provides details of a variety of accompanying measures such as the organisation of experts' meetings, workshops, conferences, and technical meetings.

THE FIRST CALL FOR PROPOSALS

20 projects related to contaminated land/water issues were funded under Key Action 1 as a result of the first call for proposals. These projects started in 2000 and are listed in Table 1; the project abstracts can be found in the Appendix.

THE CURRENT CALL FOR PROPOSALS

A new call for proposals was published on 15 November 2000 with a deadline of 15 February 2001. The general objectives for Topic 1.4 on pollution prevention under this call are the same as for the first call:

- to develop comprehensive approaches to prevent pollution of water bodies;
- to assess and minimise pollution originating from contaminated sites, waste disposal sites and sediments;
- to prevent or reduce pollution originating from agricultural practices.

There are two principal Action Lines (1.4.1 and 1.4.2) which establish links between the management of freshwater resources and contaminated land on an RDT level. Based on numerous discussion and consultation processes and taking into consideration recommendations developed at workshops, expert meetings, by networks and Concerted Actions, the new call for proposals includes the research priorities listed below. However, it is strongly recommended to visit the CORDIS website (*www.cordis.lu*) where the full text of the work programme and all relevant additional information has been made available.

Action Lines 1.4.1 Abatement of water pollution from contaminated land, landfills and sediments, and 1.4.2 Combating diffuse pollution

Topics which were identified as highly relevant for shared-cost RTD projects and other implementation tools:

- improvement of cost-efficiency of *in situ* (and near-*in situ*) remediation technologies for contaminated sites and groundwater;
- assessment of the bioavailability of pollutants (and mixtures of pollutants) and their eco-toxicological risk;
- monitoring and forecasting the temporal and spatial migration of groundwater contamination for cost-efficient risk-based site management approaches, also applied to monitored natural attenuation as a groundwater remediation approach;
- assessment of fate and impact of contaminants in dredging sludge and sediments, and sustainable solutions for their management and treatment.

Topics which should be addressed through Concerted Actions or Thematic Networks only:

- landfill-related issues, such as risk-assessment, early detection systems, monitoring of pollution from

landfills, mitigation measures in view of their better management and of the protection of surface and groundwater;
- groundwater decontamination using permeable reactive barriers;
- monitored natural attenuation for remediation of contaminated land.

Action Line 1.4.2
Combating diffuse pollution
The focus of this work is to be the assessment of the long-term fate and environmental risk associated with persistent organic pollutants, endocrine disrupting chemicals, residues of drugs and with mixtures of pollutants, and related development of mitigation measures and best management practices. The expected result is the delivery of guidelines of good land-use practices and management methods to reduce the risk of diffuse pollution.

City of Tomorrow 4.3.2
Rehabilitation and reuse of brownfield sites
The aim of this Action Line is to optimise land use in urban areas through promoting and enabling the safe and cost-effective rehabilitation and reuse of contaminated sites. Risk assessment methodologies and decision support tools should help address specific challenges. These will enable the innovative and efficient use of under and over-ground areas and reduce the cost of rehabilitation of contaminated sites.

ANTICIPATED DELIVERABLES

The **anticipated deliverables of area 1.4**, which are also listed in the work programme, read as follows:

- Action Line 1.4.1: Novel *in situ* and on-site cost-efficient remediation techniques and **(sustainable) management options** for contaminated land, groundwater, landfills and sediments.
- Action Line 1.4.2: Guidelines of good land-use practices and management methods to reduce the risk of diffuse pollution.

PREPARING PROPOSALS

A good proposal must include the following key elements:

- a clearly defined and quantified problem;
- a clearly defined concept on how to contribute to the solution of this problem;
- a cross-check of the objectives of each individual proposal against the anticipated deliverables;
- the development of a clearly defined and transparent concept (with quantifiable target) indicating with which expected results the project would contribute to the overall anticipated deliverables; and
- a detailed exploitation plan of the expected results.

CONCLUDING COMMENTS

Based on the research work which had already started in previous EU Environment RTD programmes significant progress has been made in this important RTD area. This was not only possible through the contributions of the individual research project but to a large extent also due to the intensive networking activities (e.g. NICOLE, CARACAS, CLARINET, BIOSET, CHAINET). The networking activities contributed in particular to the redefinition of the state of the art, to the identification of the most pressing problems and of ways on how RTD can contribute to the solution of these problems. Some of the existing networks will end quite soon. In order to ensure a continuity in the overall co-ordination and dissemination process, the next call invites the submission for new, well-defined Concerted Actions or Networks which will support the implementation of the revised Action Lines and support the European Commission in achieving the anticipated deliverables of these Action Lines at the end of FP5.

RECOMMENDATIONS

The information dissemination mechanisms of existing Concerted Actions can be considered an excellent tool with which to find the most appropriate partners for new projects, to obtain information on what the main problems are, and which RTD activities are going on within the individual countries. A thorough reading of the ESD work programme and of the objective and anticipated deliverables of the individual Action Lines is essential for the preparation of an excellent proposal. There is a realistic chance of getting financial support only if all criteria (see also the evaluation manual) are met and if there is no duplication with past or ongoing work. It is envisaged that successful proposals will be managed as clusters in strong co-operation with the relevant co-ordination mechanisms. It is expected that new Concerted Actions or Networks will play a strong and active role in monitoring progress achieved within individual projects or within the clusters. The Commission recognises that a presentation of 'the most sustainable management options' of freshwater in the context of contaminated land, sediments and landfills can only be achieved in a fully integrated, multidisciplinary and concerted approach involving all stakeholders. This is a challenging task which could lead to more harmonised thinking and approaches across Europe involving the relevant stakeholders.

Table 1. FP5 contaminated land R&D projects starting in 2000 under 'Key Action 1'

Contract Number	Project Acronym	No of Partners	Co-ordinating Institution	Project Title
EVK1-CT1999-00002	DIMDESMOTOM	5	Universitat Autònoma de Barcelona, Spain	Development of improved detection systems for monitoring of toxic heavy metals in contaminated groundwaters and soils
EVK1-CT1999-00003	ERAVMIS	5	Soil Survey and Land Research Centre, Cranfield University, UK	Environmental risk assessment of veterinary medicines in sludge
EVK1-CT1999-00007	DESPRAL	7	Adas Holdings Ltd., UK, Crop and Environmental Science	An environmental soil test to determine the potential from sediment and phosphorus transfer in run-off agricultural land
EVK1-CT1999-00008	CEMBA	5	Jenway Ltd., UK	CE based instrument using microsystem and biosensor technologies for bioremediation monitoring applications
EVK1-CT1999-00010	ORGONATE	3	Fraunhofer Institut für Toxikologie und Aerosolforschung, Germany	On-site remediation of groundwater contaminated by polar organic compounds using a novel adsorption technology
EVK1-CT1999-00013	TRACE FRACTURE	5	Foundation for Research and Technology, Greece	Towards an improved risk assessment of the contaminant spreading in fractured underground reservoirs
EVK1-CT1999-00014	SENSPOL (Thematic Network)	7	Cranfield Biotechnology Centre, UK	Sensors for monitoring water pollution from contaminated land, landfills and sediment
EVK1-CT1999-00015	TERRANOVA	6	Response Environmental Services Ltd., UK	Controlled environment biopiling for contaminated land treatment
EVK1-CT1999-00017	INCORE	9	UW-Umweltwirtschaft GmbH, Germany	Integrated concept for groundwater remediation
EVK1-CT1999-00021	PIRAMID	10	University of Newcastle, UK	Passive *in situ* remediation of acidic mine/industrial drainage
EVK1-CT1999-00023	MAROC	5	GBF Research Centre, Biodegradation Research Group, Germany	Molecular tools for assessing the bioremediation potential in organo-halogen-contaminated sites
EVK1-CT1999-00024	PHYTODEC	7	ALTERRA Green World Research, The Netherlands	A decision support system to quantify cost/benefit relationships of the use of vegetation in the management of heavy metal polluted soils and dredged sediments
EVK1-CT1999-00025	AGRIBMPWATER	10	CEMAGREF, Unité ADER, France	Systems approach to environmentally acceptable farming
EVK1-CT1999-00028	PEGASE	11	BRGM,FR Water Department	Pesticides in European groundwaters: a detailed study of representative aquifers and simulation of possible evolution scenarios
EVK1-CT1999-00029	GRACOS	7	Universität Tübingen, Germany	Groundwater risk assessment at contaminated sites
EVK1-CT1999-00030	PURE	13	EniChem S.p.A., Italy	Protection of groundwater resources at industrially contaminated sites
EVK1-CT1999-00033	METAL-BIOREDUCTION	10	BRGM, France	Development of technologies using the activity of sulphate and metal reducing bacteria (SMRB) to remove heavy metals and metalloids from groundwaters and soils
EVK1-CT1999-00035	PEREBAR	9	Universität Karlsruhe, Germany	Long-term performance of permeable reactive barriers used for the remediation of contaminated groundwater
EVK1-CT1999-00036	PROWATER	7	Universität Rostock, Germany	Programme for the prevention of diffuse water pollution with phosphorous from degraded and re-wetted peat soils
EVK1-CT1999-00042	IMSIS	8	Fraunhofer Institut für Physikalische Messtechnik, Germany	*In situ* monitoring of landfill related contaminants in soil and water by infrared sensing

APPENDIX

EVK1-CT1999-00002
Development of improved detection systems for monitoring of toxic heavy metals in contaminated groundwaters and soils (DIMDESMOTOM)

Problems to be solved
Toxic heavy metals (THM) are well-known pollutants from both natural or anthropogenic sources. Their deposits in solid or liquid solutions have several ways to spread out (including both physical and chemical transformations) and thus to get into the trophic chain. The current '*in situ*' THM detection systems are generally limited to spectrophotometric chemical test kits. These offer the convenience of field analysis but have several important limitations:

- speciation is not achieved, only total content is determined;
- chemical and physical interferences to measured signal can be dramatic;
- still require a high degree of user competence.

Thus, data are poor to determine trends in pollution and to contribute to a proper risk assessment. A solution to this problem will directly contribute to the EU policy for environmental information and protection of groundwaters and soils (EU council inter-institutional dossier 97/0067 (SYN).

Scientific objectives and approach
The present project is focused on throwing light on this problem by identifying the contamination trends of these pollutants (including chemical speciation and metal mobility factors) as well as determining the efficiency of the remediation processes that are applied to such contaminated sites.

To accomplish these objectives, the research activities have been planned as follows. The project will develop and validate novel selective and robust sensing devices, including chemical sensors and biosensors and biomimetic systems for on-line operation and real time measurements of THM (toxic heavy metals) present in contaminated soils, groundwaters and surface waters. This general contribution will be accomplished by the specific investigations:

- elaboration and validation of electrochemical biosensors/immunosensors and screen-printed electrodes for analysis of THM in contaminated soil, surface waters and groundwaters;
- determination of THM chemical speciation and its trends of contamination;
- designing and construction of a portable detection system for THM determination;
- integration of the data generated by the new devices into a decision-taking scheme based on GIS (geographical information system) to provide a more accurate and inexpensive risk assessment.

Expected impacts
The developed detection systems will be validated in laboratory and field trials and then actively used for the monitoring of pollution levels in contaminated European sites and landfills and for controlling the efficiency of remediation activities. The GIS technology will enable an efficient use of the sensing systems. It will take benefit from the new type of data for producing a more accurate and flexible evaluation of risks, targeted to the case of large sites contaminated with heavy metals. The project is also addressed to European regulation by determining monitoring procedures that will assess decisions for cleaning up toxic heavy metal contaminated sites. Moreover, the developed procedures will allow for data to be obtained about the state of groundwaters and soils (in terms of metal content) that can be included in already existing databases such as those managed by the European Environmental Agency. The problems related to industrial activities (i.e. metal finishing industry, production of fertilisers, urban sludge treatment, mining activity and consequences of mining tailing spills) are currently under strong consideration due not only to limitations on cost-effective and technological competent processes but also to the lack of appropriate decision making procedures. The final goal is to introduce the developed monitoring systems to markets, in which present industrial products have not penetrated because they are too expensive and/or require excessive maintenance or calibration or because their size is simply too large.

EVK1-CT1999-00003
Environmental risk assessment of veterinary medicines in sludge (ERAVMIS)

Problems to be solved
Veterinary medicines are widely used across Europe and are released to land either directly or indirectly through the application of sludge. The medicines may persist and have the potential to run off to surface water or leach to groundwaters where they could impact human and environmental health. Under EU Directive 81/852/EEC an environmental risk assessment is required for certain veterinary medicines. However, unlike other classes of chemical (e.g. pesticides, nutrients and industrial chemicals) the environmental impact of veterinary medicines is poorly understood. Consequently current risk assessment procedures are simple and have been developed to predict 'worst case' concentrations. Moreover, the approaches have not been validated. There is therefore a need to generate data on the behaviour of a range of veterinary medicines in the environment in order to develop an improved understanding of those factors and processes that affect their fate and to refine and validate current risk assessment approaches. This study, which will combine laboratory, semi-field, field and modelling studies, will investigate sorption, degradability, ultimate fate and ecotoxicity of a range of veterinary medicines. On the basis of the studies, rules, models and experimental approaches will be recommended for the assessment of veterinary medicines that will be used in the EU in the future. A range of scenarios will be developed to assess the

risk of veterinary medicines across Europe and finally, a tiered approach will be developed for use by industry and regulators involved in assessing the environmental risk of veterinary medicines.

Scientific objectives and approach

The overall objective of the project is to develop approaches for assessing the environmental impact of veterinary medicines released through the spreading of manure, slurry and sludge. The specific aims of the study are: 1) to identify those factors and processes controlling the degradability of veterinary medicines in the environment; 2) identify those factors and processes controlling the sorption of veterinary medicines in manure, sludge, soil and water; 3) assess the effects of veterinary medicines on microbial functioning in soils; 4) assess the effects of veterinary medicines on soil organisms; 5) assess the environmental distribution of a range of veterinary medicines at the semi-field and field scales; and 6) use information from 1–5 to develop exposure assessment models, scenarios and risk assessment approaches for use by regulators and industry across Europe. These objectives will be achieved using a combination of laboratory, semi-field and modelling studies.

Expected impacts

On the basis of the project results, a guidance document will be produced for use by industry and regulators involved in the risk assessment of veterinary medicines. It is envisaged that this document will be used in the future to perform more accurate assessments of the environmental risk of groundwater and surface water contamination by new and existing veterinary medicines and to identify appropriate management options for veterinary medicine sludges. The results of the study will also be made available to the Veterinary International Co-operation on Harmonisation (VICH, which comprises representatives from industry and regulators from Europe, America and Japan) so that it is likely that the results of the study may also influence risk assessment approaches applied internationally.

EVK1-CT1999-00007

An environmental soil test to determine the potential for sediment and phosphorus transfer in run-off from agricultural land (DESPRAL)

Problems to be solved

The transport of soil particles and associated pollutants in run-off from agricultural land is increasingly being recognised as a factor responsible for the deterioration in the biodiversity and quality of freshwaters. Phosphorus (P) has been identified as a key limiting nutrient in freshwater systems and national R&D programmes have identified the importance of soil particles in P transfer causing eutrophication. National regulators need to maintain water quality for a range of users and seek methods to both identify where suspended pollutants originate within a catchment and design practical cost-effective land management options to prevent or control their transfer to the watercourse taking into account local conditions. The programme of work is relevant to EU policies aimed at standardising methodologies for assessment and prevention of pollution, developing environmentally sustainable farming practices and protecting watercourses from deterioration in ecological biodiversity and quality.

Scientific objectives and approach

The development of cost-effective methods to reduce the risk of diffuse pollution and/or eutrophication of surface and groundwaters requires accurate identification of high risk contributing areas and an understanding of the relative contribution of natural geographic factors and agricultural management factors influencing the transport of soil particles and associated P within catchments. To achieve these aims, a simple environmental soil P test uniquely based on soil dispersivity will be developed to routinely quantify soil susceptibility to particle transfer and the degree of particle enrichment with P due to agricultural practices. The test will be calibrated against suspended sediments collected in run-off from simulated and natural storm events using EU soils of different physical and chemical characteristics from experimental plots with known management histories. The test will be incorporated into existing risk assessment methodology and its usefulness as a management tool in identifying critical source areas evaluated at the farm and catchment scale. Comparisons of novel cultivation practices in selected high loss risk areas and soils will be undertaken to identify appropriate and cost-effective remedial options in catchments with diffuse pollution problems. In collaboration with an end-user, guidelines on best land management practices and their relative cost-effectiveness will be produced and disseminated to relevant stakeholders. Adoption of the test will enable more precise identification of high P loss risk areas than is possible with conventional methodologies and the work will support EU COST Action 832 on ‘Quantifying the Agricultural Contribution to Eutrophication’.

Expected impacts

The results of the project will lead to the development of management tools and guidelines that can be disseminated and used by end-users as part of integrated river basin management strategies for the assessment and control of diffuse pollution. Increased biodiversity in natural waters, improved water quality for a range of users, and prevention of potential health hazards associated with algae toxins will enhance the quality of life and help reduce the adverse environmental and economic impact of eutrophication.

EVK1-CT1999-00008

CE based instrument using microsystem and biosensor technologies for bioremediation monitoring applications (CEMBA)

Problems to be solved

Throughout Europe bioremediation is being utilised to remediate sites that have been contaminated with hazardous waste. The toxic pollutants at these sites may consist of metallic elements, organic chemicals, petrochemicals, pesticides, biologically hazardous waste and other hazardous materials associated with the disposal of industrial by-products and domestic waste.

These areas pose health risks by resultant contamination of the land and ultimately water reserves.

Sampling and analysis of soil, groundwater and leachate is an essential part of the risk assessment process, in the evaluation of polluted sites as well as in the ongoing tracking of a remediation programme at a landfill site.

Scientific objectives and approach
The aim of this work is the development of a cost-effective, rapid, portable analysis system for the measurement of bioavailable toxic metal or organic contaminants, which may be present at natural attenuation landfill sites requiring remediation. The proposed system is intended to be used as a tool in the monitoring or characterisation of a site by discrete measurement. A portable system will be developed, comprising a miniaturised extraction and separation device employing capillary electrophoresis, detectors for specific analyses (metals or organics) by biosensors or immunosensors and dedicated instrumentation to process the signals generated. Development of extraction procedures for the analysis of plant material will also be part of the project, to be used when phytoremediation is employed as part of the site remediation process.

Biosensors to detect toxic metal will use bioengineered proteins to interact with bioavailable metals on an electrode surface. The conformational change in the engineered protein will allow a specific metal to be detected. Extraction employing superheated water extraction and enzyme immunosensors will be used to monitor organic pollutants (PAHs and PCBs).

Expected impacts
Pollution of the soil and groundwater by metal and hydrocarbon contaminants is an ongoing and complex environmental problem. Within the EU, the proposed directives on landfill sites require that countries should report on the capacity, operation and environmental conditions of landfills. Cost-effective alternatives to traditional, physical and chemical methods of remediation are required, together with methods to monitor the remediation process.

Individual member countries will differ in assigned priorities, activities and focus but all have in common the need for effective and accurate measurement of contaminants.

EVK1-CT1999-00010
On-site remediation of groundwater contaminated by polar organic compounds using a novel adsorption technology (ORGONATE)

Problems to be solved
Groundwater is the main source of drinking water production in most regions of Europe. In many areas this groundwater is contaminated by a variety of mainly organic pollutants threatening the drinking water supply in the future. Existing methods for remediation of groundwater have limitations and disadvantages, in particular, when used on-site. In general, very polar compounds have not been removed by these techniques.

Scientific objectives and approach
A novel technology will be developed which allows the removal of organic contaminants from polluted groundwater. Groundwater clean-up is achieved by adsorption of the pollutants onto organic polymers of small particle size packed in radial beds. The surface of the polymer particles will be modified to reduce pore plugging. After loading with pollutants, the polymers can be regenerated on-site. Explosives and phenols have been selected as model compounds to test this new technology. Contamination by these compounds is widespread in Europe. Moreover they are representative for polar compounds in general, which are difficult to remove from groundwater.

The project starts with laboratory studies on the adsorption process (determination of adsorption isotherms and breakthrough volumes) followed by laboratory studies on the regeneration process. Based on the results of laboratory studies, mathematical simulation models will be developed which allow the design and finally the construction of the pilot plant. In the final part of the project this pilot plant with a capacity of 1–3 m^3/h will be tested in the field and further optimised.

Expected impacts
It is expected that the new technology will also allow an efficient remediation of polluted groundwater in remote areas, as one means to ensure the sustainability of groundwater into the next century. Thus the project contributes to the goal of maintaining the quality of life and health in the EU. Finally, the clean-up of contaminated groundwater preserves and enhances the quality of the environment in general and the availability of natural resources.

EVK1-CT1999-00013
Towards an improved risk assessment of the contaminant spreading in fractured underground reservoirs (TRACE FRACTURE)

Problems to be solved
Soil and groundwater contamination by hazardous substances is becoming one of the most significant problems for the environmental and economic policies of the EU. Macroscopic simulators of the transport of non-aqueous phase liquids (NAPLs) in fractured porous media are required for the implementation of fast and cost-effective risk assessment procedures to contaminated fractured sites. In spite of the progress that has been accomplished on the development of intelligent numerical solvers of the multiphase transport equations in fractured reservoirs, there is a lack of fundamental knowledge concerning the relations of the flow physics with the complex morphology of fractures as well as self-consistent phenomenological models of the mesoscopic transport coefficients (e.g. absolute permeability, relative permeabilities, hydrodynamic dispersivities) of fractured media. Such models, properly integrated into industrial macroscopic simulators, are required for the development of generalised, cost-effective and reliable risk assessment methodologies, which are expected to contribute to: (i) the mapping of the huge number of contaminated sites in the EU; (ii) the rational design of clean-up strate-

gies for the contaminated aquifers of the EU; and (iii) the development of new EU policies for the sustainable management of soils as natural resources.

Scientific objectives and approach

The overall objective of the project is threefold: (a) to develop new, self-consistent and true-to-mechanism phenomenological models to describe the transport coefficients of fractured porous media as functions of the fracture morphology and fluid rheology; (b) to integrate the new phenomenological models into a novel and reliable numerical simulator of macroscopic contaminant transport in fractured underground reservoirs; and (c) to use the new numerical tool in the development of a generalised methodology of risk assessment and rational design of remedial strategies for contaminated fractured aquifers. In the present project, two different generic contaminated fractured sites located in Europe will be selected. A novel method of fracture characterisation will be developed and will be applied to samples of both sides. The one-phase flow, two-phase flow and solute dispersion of Newtonian and non-Newtonian fluids through fractured porous media will be studied experimentally on artificial models having structural properties similar to those of the investigated sites, and will be simulated by using methods of the statistical physics of disordered media and computational fluid mechanics. All these analyses will result in novel and true-to-mechanism phenomenological models of one-phase flow, immiscible two-phase flow and hydrodynamic dispersion in fractured porous media. The self-consistency of all models will be evaluated with reference to lab-scale experiments. The new models will be integrated into an industrial simulator of the contaminant transport in fractured reservoirs. The new simulator will be evaluated with reference to old and new field data, collected from both sites, and will further be used as a tool in the development of a generalised methodology of risk assessment and design of cost-effective and sustainable remedial strategies for contaminated fractured aquifers.

Expected impacts

The know-how and tools that will be developed in the course of this project are expected to be available to research organisations, environmental companies and oil and gas industries throughout Europe. With the use of the novel methodologies, the risk assessment of fractured contaminated sites will become cost-effective and reliable, whereas fast decisions of low financial risk will be able to be taken about the remediation of such sites. In this manner, both the competitiveness of the technology suppliers is expected to increase in the European and international markets and the quality of the life of people living close to contaminated areas is expected to be improved.

EVK1-CT1999-00014

Sensors for monitoring water pollution from contaminated land, landfills and sediment (SENSPOL)

Problems to be solved

The requirement for *in situ* monitoring of environmental pollutants places sensor devices clearly at the core of any programme to develop technology for remediation and techniques for enhancement of natural attenuation processes. Chemical and biosensor technologies are capable of measuring both existing and new parameters of relevance to the environment and of monitoring several parameters simultaneously under real operational conditions. They can be deployed to identify pollution trends and to control the efficiency of remediation activities. Toxicological risks of complex mixes of pollutants can be assessed using biosensor technologies and biomimetic systems.

The SENSPOL Thematic Network will enhance the development of chemical sensors, biosensors and biomimetic systems for practical applications in the abatement of water pollution from contaminated land, landfills and sediment. It will also aid EU decision making in the environmental area.

Scientific objectives and approach

The SENSPOL Thematic Network will target the accelerated development of chemical sensors, biosensors and biomimetic systems to provide sensitive and robust devices for monitoring environmental pollutants in water and contaminated soil and sediments. The objective is to provide *in situ* monitoring of environmental pollutants in water and contaminated soil and sediments. The work programme is based on a series of European meetings, a centralised information facility and a broad collaboration programme. SENSPOL will cluster the sensor development activities in the EU's environmental projects and act as a catalyst for the advancement of European technology for monitoring the environment. The resulting sensors will be capable of on-line operation and real-time measurements of pollutants and their effects.

Expected impacts

SENSPOL will contribute to improving the quality of the environment by providing new information on the state of pollution of European water resources and of soil and sediments that might pollute the water supply. The information will be valuable in assessing risks to human health from contaminated water, soil and sediments. The data obtained using sensors can be used to facilitate optimisation of remediation technologies and natural attenuation processes. The sensor technologies developed will provide new opportunities for European industry.

EVK1-CT1999-00015

Controlled environment biopiling for contaminated land treatment (TerraNova)

Problems to be solved

The proposal for an EU Action Programme for Integrated Groundwater Protection and Management (COM(96) 315 final), adopted by the Commission in August 1996 and the proposal for a Water Framework Directive (COM (97) 49 final) issued in February 1997, which aim to protect groundwater, inland surface waters, estuaries and coastal waters and groundwater, will form the framework for the whole of water policy. The

Water Framework Directive would require Member States to prepare a programme of measures to attain 'good' surface water and groundwater status by the end of 2010. There is a huge amount of contaminated land across Europe. Water transfer through these sites can leach contaminants into the groundwater. The TerraNova project will develop a rapid bioremediation process, which will enable SMEs to make a real contribution to cleaning up that contamination.

Scientific objectives and approach

Biopiling is a commonly used technique for bioremediating contaminated land. The TerraNova project aims to bring together the skills of microbiologists, contaminated land treatment engineers, heating engineers, chemists, analysts and computer/control engineers to engineer the biopile as a *bioreactor* to create optimum condition for very rapid bioremediation. The TerraNova process aims to level out the supply of nutrients, of air and even the temperature across the biopile and thus greatly reduce the fluctuations in the rate of bioremediation, giving a process which could reduce the treatment time by 70%.

Deliverables:

- design and build a laboratory scale TerraNova biopile involving a monitoring/control unit, heating ventilation and air conditioning unit (6 months);
- operate and evaluate the results from the laboratory TerraNova (12 months);
- design and construct a field scale TerraNova biopile (18 months);
- operate and evaluate the results from the field TerraNova (33 months);
- evaluate the applicability of TerraNova across the EU in terms of techno-commercial, regulatory and marketability (0–36 months);
- produce a technology transfer package for SMEs (30–36 months).

Expected impacts

Contaminated land treatment is fundamentally a low technology business involving bulldozers and diggers. Because of this an underlying objective is to provide a low technology, robust process, with robust on-line monitoring and control, which can be used by unsophisticated SMEs. TerraNova is very much about employment, the project is about transferring the technology through a licensing process across Europe so that the huge market can be exploited by those SMEs. The whole concept of TerraNova is to clean up contaminated soil in a closed safe fashion and do it quickly and efficiently. It will therefore help quickly to reduce human exposure to harmful chemicals and pollutants and improve the quality of life and health for European citizens.

EVK1-CT1999-00017
Integrated concept for groundwater remediation (INCORE)

Problems to be solved

Groundwater pollution in industrialised sites is a general problem in a variety of European cities. Most are located in river basins and use groundwater for water supply from local shallow aquifer systems. Within the last decades changes in land use and ownership have resulted in complex contamination patterns, such as heterogeneous distribution of contaminants, different contaminants and large subsurface areas. Industrial development and the need for groundwater conservation are in acute conflict. Today, large amounts of private and public money are spent to identify and assess point sources of contamination without being able to reliably quantify their impact on the groundwater quality: numerous remediation schemes are operated without an economical evaluation of their long-term performance. Throughout Europe numerous guidelines and directives exist at the national level, focusing on the characterisation and evaluation of individual sites – but none of the approaches is applicable to industrial regions as a whole.

The INCORE approach supports the revitalisation of urban industrial land in line with the Aalborg Charter of European Cities and Towns Towards Sustainability. Major impacts deriving from contaminated land are groundwater contamination and restrictions on land use. INCORE emphasises the sustainable use of groundwater resources in line with the key objectives of EU water policy.

Scientific objectives and approach

INCORE aims at providing a cost-efficient technical-administrative set of tools to optimise investigation, evaluation and management of contaminated groundwater and land in urban industrial areas, considering regional aspects such as complex land-use patterns, land-use specific contamination and the extent of urban industrial areas. This will allow the revitalisation of groundwater resources and soil in these areas. Innovation of current scientific, technical, economic and administrative methodologies will be tackled.

INCORE focuses on the development and partial implementation of a new approach to contaminated land assessment and revitalisation in urban industrial areas comprising three cycles: (a) the investigation of groundwater contamination emission at the scale of entire sites, (b) the evaluation of the contamination source zones and (c) the development of emission oriented remediation strategies. The major advantage of the new approach is that the number of sites to be considered is reduced within each cycle. Furthermore, cost-effective revitalisation measures could be implemented based on the level of tolerable groundwater emissions. To achieve the project's goals, the following deliverables have been defined which will deliver the necessary methods/tools for the implementation of the new cycle approach:

- Application strategies and recommendations for investigation of contaminated groundwater and land in industrialised urban areas. Methodology for optimal selection, combination and application of innovative remediation technologies.
- Recommendations to harmonise, improve and accelerate administrative work with respect to PPP-Models in the integral abatement of water pollution from contaminated land, landfills and sediments in Europe.

Expected impacts

INCORE will develop new technical and administrative tools under real-world conditions to provide an important basis for the development of future EU directives on contaminated land assessment.

The revitalisation process is expected to have an economic impact by providing incentives for new business settlements in 'brownfields' and avoiding the use of 'greenfield' areas. The public authorities will be given the chance to solve negative site aspects, improve and regain the quality of life and environment in urban areas by achieving and maintaining regional groundwater at high quality, supporting the sustainable use and conservation of regional groundwater resources and furthermore sustainably develop their city.

EVK1-CT1999-00021

Passive *in situ* remediation of acidic mine/industrial drainage (PIRAMID)

Problems to be solved

Long-term water pollution from abandoned mines and associated industrial sites is a significant problem in many EU Member States and Candidate States. Recent developments of 'passive', ecologically-friendly *in situ* remedial methods for such pollution, including subsurface reactive barriers and various forms of wetland, have hitherto developed in an uncoordinated manner. PIRAMID aims to draw these developments together, and to foster further innovations to make the technology applicable to a wider variety of abandoned mine waters. Guidelines for the practical use of the technology will be drawn up and widely disseminated. In this way PIRAMID will assist in the implementation of the Water Framework Directive.

Scientific objectives and approach

- Assemble a European database of experiences with passive *in situ* remediation of acidic mine/industrial drainage, covering both surface and subsurface passive in-site remediation (PIR) systems.
- Develop process-based models of PIR system performance to support improvement of future designs.
- Critically evaluate the potential applications of PIR in areas of Europe which still do not have the technology.
- Test in lab and field novel approaches to PIR for other specific contaminants and using novel substrate.
- Develop engineering guidelines for PIR application at new sites throughout the EU.

Expected impacts

- Rendering feasible remediation projects that would not otherwise have been undertaken.
- Development of environmentally-friendly remedial measures which can make a contribution to the practical implementation of the Water Framework Directive.
- Assist Candidate States in attaining environmental quality in line with EU requirements.
- Developments of PIR technology which will be applicable in future to other pollutants, such as nutrients or man-made organic compounds.

EVK1-CT1999-00023

Molecular tools for assessing the bioremediation potential in organohalogen-contaminated sites (MAROC)

Problems to be solved

Chlorinated hydrocarbons are the most important and widespread class of contaminants of soil and groundwater in all European countries and environmentally friendly methods have to be developed to abate this pollution. Many examples of bacterial transformation and, even, mineralisation of these compounds have been found. In field situations, stimulated or natural (intrinsic) bioremediation may, therefore, be a suitable remediation strategy for reducing risks. However, in practice, it is difficult to predict the bioremediation potential of the indigenous microbial polluted sites. Hence, there is a need for the development of effective, easy to handle tools for predicting degradative potential or for monitoring the effective stimulation of catabolic pathways *in situ*. These tools should not be dependent on the culturability of contaminant-degrading organisms but, rather, be directed at the detection of the genes specific to the microorganisms and gene encoding enzymes that catalyse the key reactions in the degradation pathways of contaminants.

Scientific objectives and approach

Molecular detection methods will be developed and optimised for the monitoring of bioremediation processes. A combination of detection of specific microorganisms, detection of catabolic genes and transformation activity, all *in situ*, will allow the accurate analysis of *in situ* natural attenuation. Results of the characterisation of intrinsic potentials of organohalogen-polluted sites by classical microcosm studies will be used to assess the usefulness of the molecular tools developed during the time-course of the project.

A knowledge base created by the detailed genetic and biochemical characterisation of a collection of DNA segments encoding catabolic genes will be used for the development of probes and primers for extracting the broadest possible diversity of genes from the environment. A database relating genetic structure to metabolic function for various key enzymes of halogenated hydrocarbon degradation will be built up and after optimisation of protocols for isolating DNA and RNA from environmental samples, as well as the adaptation of quantitative PCR methods, used for the development of specific probes and primers to analyse and quantify the presence and expression of degradative pathways in contaminated samples, to characterise enrichment cultures and to monitor the evolution of dechlorinating activity in microcosms. Results of this validation phase will be used to optimise the molecular tools already available. Finally, newly developed and optimised methods will be converted to an economic method to identify and quantify by molecular methods the natural attenuation potential of contaminated sites.

Expected impacts

The project will directly contribute to better pollution and waste manage-

ment and reduce exposure to harmful pollutants by increasing our understanding of the biochemical factors that are critical in degradation of halogenated pollutants in the environment and thereby allowing the rational manipulation of biological or other parameters at a polluted site.

The application of rapid molecular culture-independent detection methods for biomonitoring purposes will allow accurate analyses of *in situ* natural attenuation and stimulated *in situ* biorestoration, leading to decreased costs of biotechnological remediation. Therefore, the results of this project will increase the market for suppliers of biotechnological waste-treatments and consultancy in environmental biotechnology.

The proposed efforts will not only help in facilitating biological remediation and stimulate the use of those techniques in Europe. We anticipate that the project will also lead to automated high-throughput methods that allow a routine use and will become available to SMEs working on bioremediation and thereby will lead to the development of a technology for industrial use, will foster the use of environmentally friendly biological remediation techniques and generally support the use of new molecular methods to monitor biological processes.

Furthermore, the stimulation of bioremediation techniques directly contributes to the preservation and enhancement of the environment.

EVK1-CT1999-00024
A decision support system to quantify cost/benefit relationships of the use of vegetation in the management of heavy metal polluted soils and dredged sediments (PhytoDec)

Problems to be solved
Phytoremediation, i.e. the use of vegetation to reduce the environmental impact of heavy metals (and other pollutants) in soils and dredged sediments is a promising emerging 'green' soil management and soil remediation technology to reduce emigration of heavy metals to groundwater and surface water. Scope and limitations are however not fully known yet. This hampers a broader practical application or, even worse, leads to applications in situations where other techniques are more appropriate and vice versa. PhytoDec aims at developing a straightforward tool, that provides end-users and policy makers with a reliable and validated decision support system (DSS) for the design of tailor-made soil remediation strategies. As soil pollution with heavy metals is still widespread in Europe, the appearance and consolidation of an alternative green technology is relevant for EU policies, especially when concerning extended areas of moderate pollution levels, where high costs do not permit conventional technological solutions. A specific potential application area is the use of phytoremediation when preparing set-aside agricultural land for reforestation and nature development which continues to be a major EU policy. The future extension of the EU to include vast heavy metal polluted areas in Eastern Europe will extend phytoremediation applicability and therefore sufficient know-how to develop adequate remediation strategies.

Scientific objectives and approach
PhytoDec aims at the construction of a DSS to assess the practical applicability of phytoremediation in quantitative terms: together with an annexed analytical protocol for monitoring purposes, the DSS constitutes the main project deliverable. The DSS enables the assessment of the practical applicability of the use of vegetation to abate soil pollution, in comparison to other soil remediation options, through relating cost parameters to environmental effectiveness parameters. The approach, adopted to reach this main project objective within the four years of project duration starts with filling the most important remaining process-related knowledge gaps that greatly affect the practical applicability of phytoremediation, including:

- long-term cost/benefit relationships:
- the importance of environmental side-effects:
- prediction of phyto-extraction duration, based on soil chemical and plant physiological processes.

During DSS-construction extensive attention is given to the validation of the DSS and more specifically its process-related calculation routines. This is achieved through carrying out mesocosm experiments and field trials during all four years of project duration. Extension to end-users starts in an early project phase, making use of all partners' scientific, political and potential end-user networks. At the end of the project a workshop will be organised to finally present the DSS to a representative and influential group of end-users at a European level.

Expected impacts
When successful, PhytoDec will provide end-users and policy makers in Europe with a validated tool (DSS) to decide whether phytoremediation is applicable or not at their specific heavy metal polluted sites. The DSS relates scientific (soil remediation effectiveness and duration) aspects to cost aspects (land value during remediation, monitoring costs etc.) and social aspects (public acceptance and landscape values during and after phytoremediation etc.). It contributes to a better and healthier environment as it creates possibilities to reduce environmental impacts of extended polluted areas at a lower cost, thus permitting community funds to be used for other priority environmental targets. Its main impact therefore is to contribute to more effective and equilibrated applications of emerging soil remediation techniques, avoiding financial losses for tax payers, policy makers and local government, owners of polluted sites and commercial companies involved in soil remediation and soil management.

EVK1-CT1999-00025
Systems approach to environmentally acceptable farming (AgriBMPWater)

Problems to be solved
Rising concern about agricultural non-point water pollution has led many regulatory measures to be proposed. Agri-environmental programmes have been implemented in the different EU Member States

according to the Commission Regulation 2078.92. Best management practices (BMPs), one of the most popular tools, have rarely been assessed in a fully satisfying way. This project aims at providing planners with a grid which would allow a comparison between BMPs in terms of environmental efficiency, economic cost and potential acceptability by farmers. Expected results should help Member States choose the most appropriate measures and ways for an efficient implementation of BMPs with the support of scientifically validated technical and economic recommendations, thus contributing to various EU policies such as CAP, Instruction 91/676/EEC, Instruction 80/778 EEC and more generally European water policy.

Scientific objectives and approach

A comparison between different existing or simulated BMPs will be carried out through a cost/effectiveness assessment along with the study of their acceptability by farmers. Effectiveness will be assessed as the evolution of water quality resulting from BMP implementation in experimental watersheds. Particular efforts will be carried out to improve BMP representation in hydrological models, as they can take various forms (landscape structures, agronomic recommendations). Spatial modelling, at various scales, will be used to define critical areas where efforts should be concentrated. As for costs, efforts will concern the evaluation of both direct and indirect costs induced by BMP implementation. When studying diffuse pollution, individual contributions and de-pollution costs are not known and have to be assessed. Direct costs will therefore be estimated through the definition of contract menus in a principal/agent modelling framework. Indirect costs will be estimated as the impact of BMPs on all other branches of the economy with the use of a general equilibrium model. A cost-effectiveness ratio will be calculated for each studied BMP, allowing a comparison of possible alternatives. Unfortunately, farmers do not apply BMPs as would be desirable. Possible explanations are that of their low environmental commitment and insufficient implementation practices. Extensive interviews will be carried out to account for the social dimension of farmers' decision making process. In addition, complementary interviews with land managers will help in finding out what are the implementation practices used and problems encountered. This will aim at defining new negotiative implementation methods which will be evaluated in a demonstration project involving both local land managers and farmers.

Expected impacts

Short-term results will consist of a potential cost-effectiveness ratio. Based on the experience of case studies, the project will provide a methodological guideline designed to assess BMPs on the three dimensions of effectiveness, cost and acceptability. Thanks to this integrated assessment of existing and potential BMPs, the expected selection grid should contribute to building a decision support tool both for the EU to implement the eco-conditionality regulation and at a local scale, for land managers and local planners to face water resource management related issues.

EVK1-CT1999-00028

Pesticides in European groundwaters: a detailed study of representative aquifers and simulation of possible evolution scenarios (PEGASE)

Problems to be solved

Pesticide concentrations above the 0.1µg/L drinking water limit have been reported in many groundwaters (GW) used for drinking water supplied in Europe. Questions as to why it happens and how it will evolve in the near and distant future cannot be answered at the moment. Because the GW is used extensively for drinking water purposes, this is a problem of true European dimension.

PEGASE will focus on delivering performance-assessed tools to predict the possible evolution of GW contamination by pesticides at the aquifer scale and to assess the socio-economic implications of alternative scenarios aiming at GW quality restoration or protection. An improved knowledge of the relative importance of processes involved in pesticide transport to and in the GW of representative aquifers will benefit the harmonised regulatory procedure and eventually lead to reductions in environmental deterioration, benefiting the community at local, regional, national and international levels. The work to be conducted through PEGASE will complement European policy objectives by providing tools that will help in implementing the Member States policies across Europe by both legislators and stakeholders.

Scientific objectives and approach

The global objective of PEGASE is to enable predictive modelling of pesticide contamination of representative European aquifers and assessment of socio-economic implications of the present and future contamination. Specific objectives and innovations are the:

- Production of high quality data sets with intensive (36 monthly samplings) and extensive (land use, pesticide applications, soil vadose zone and aquifer characteristics) monitoring of aquifers ranging from a 1 hectare area of a sandy aquifer with GW table < 2 m bgl to a karst aquifer with GW> 10 m bgl;
- Development of mechanistic and semi-empirical tools dedicated to the spatialized modelling of pesticide contamination of GW with: (i) operating links between root zone models and aquifer models; (ii) consideration of non-equilibrium phenomena; and (iii) incorporation of uncertainties associated with the field data and the results from transport models.
- Performance assessment of those tools using the data of the first 24 months monitoring for calibration and assessing the predictive capacity (extrapolation step) by comparing predicted GW levels and pesticide concentrations with the values of the third hydrological cycle monitored.
- Socio-economic assessment of alternative scenarios including changes in land use and agricultural practices aiming at GW quality restoration or protection in a context of sustainable development.

Expected impacts

A better understanding of how pesticide concentrations in GW are most likely to evolve over time (a key objective of PEGASE project) will enable a more cost-effective configuration of the treatment plants and result in a cheaper water supply for consumers, thereby yielding considerable benefits to end-users of GW resources. The knowledge provided by PEGASE will also help avoid very restrictive land practices to be recommended or imposed that would not take account of site-specific conditions (e.g. a particularly slow GW recharge, or long transit time of the water flux through a very thick unsaturated zone). Finally, by identifying areas least at risk of GW pesticide contamination, PEGASE will enable the available financial resources to be allocated to the most vulnerable areas, thus maximising the improvement society may expect from its limited financial and natural resources. All stakeholders will be associated with the socio-economic work in PEGASE, ensuring a choice of scenarios that may possibly be implemented and a true assessment of their direct and indirect environmental implications.

EVK1-CT1999-00029

Groundwater risk assessment at contaminated sites (GRACOS)

Problems to be solved

Contaminated land in Europe poses a serious problem with respect to soil quality and risk of spreading of pollutants into other compartments of the environment. The major concern at most contaminated sites is the risk of groundwater pollution by organic and inorganic compounds. Since the remediation of all of the contaminated sites in Europe is economically not feasible, groundwater risk assessment procedures are needed for the ranking of sites, decision making on further use and remedial actions. In contrast to existing procedures this project concentrates on the development of methodologies for the assessment of the mobile contaminant fraction in contaminated soil and waste material (i.e. the contaminant fraction which would reach the aquifer). It will allow the determination of the long-term contaminant release rates and the overall emission of pollutants into the groundwater at contaminated sites. The most important innovations expected will be more harmonised and integrated guidelines for groundwater risk assessment in Europe and beyond.

Scientific objectives and approach

The procedures to be developed take the form of a scenario approach, as it is intended to be generally applicable to different situations in terms of classes/combination of pollutants and site-specific conditions, such as climatic conditions, permeability and distance between contamination and groundwater table. Such a scenario approach will allow the determination *a priori* whether under given site conditions (subsurface permeability, distance to groundwater table, type of material) and contaminant properties (volatile/non-volatile/water soluble etc.) a minor, medium or high risk of groundwater pollution exists.

The validation of these new risk assessment procedures will be done: (1) in a well-controlled field experiment which comprises an emplaced source of a hydrocarbon mixture consisting of volatile to semi-volatile (partly) biodegradable compounds; (2) laboratory and field investigations for the quantification of contaminant transfer rates across the capillary fringe for specific scenarios; and (3) column leaching tests for the quantification of the mobile contaminant fraction in various contaminated soils and waste materials (e.g. slag, bottom ash, construction/recycling materials). To cover as many different site-specific scenarios as possible, the project involves numerical modelling of vapour phase contaminant transport in the unsaturated zone and long-term leaching of contaminants from specific materials.

Expected impacts

The most important deliverables of the project will be guidelines for groundwater risk assessment which for certain scenarios, compound classes and material types does not require or requires only minor field or laboratory investigations. Therefore, it would significantly reduce the costs to society of dealing with the legacy of industrial pollution. The end-users will be the governments/regulators and finally the citizens of Europe who will benefit from a harmonised, more rational economic and integrated approach to environmental regulation.

EVK1-CT1999-00030

Protection of groundwater resources at industrially contaminated sites (PURE)

Problems to be solved

The abatement of pollution at industrially contaminated sites is a particular problem when more than one source of contamination and/or type of pollutant is present. Since local conditions are site-specific, each site requires a unique solution. Key aspects of this problem at the European level are addressed by PURE.

1. Recalcitrant organohalides, hydrocarbons (in particular BTEX) and heavy metals are considered 'priority' pollutant families and can migrate from industrial sites via the groundwater.
2. Site characterisation to allow design of the remediation approach and the monitoring of the remediation process itself are time-consuming and expensive.
3. *In situ* technologies, in particular those based on biological processes are still under evaluation.

The management of contaminated sites and the protection of groundwater are key aspects of the EU environmental policy areas and will benefit from the PURE programme.

Scientific objectives and approach

By putting together problem owners, end users and R&D performers (mostly members of NICOLE), PURE aims to develop a multidisciplinary, widely applicable approach to protecting groundwater resources. Four sites, selected for their particular contamination and hydrogeological characteristics which are in some ways common to the majority of polluted sites in Europe, have been targeted for study.

PURE is composed of two sub-projects:

- SICHAMORE: The development of cost-saving solutions to fully describe the contaminated site through reduction of sampling analytical load and to identify the optimal remediation process.
- TREES: developing preferably *in situ* methods to treat: (1) the pollution core in the soil and hence prevent the migration of contaminants to groundwater; and (2) the contamination plume.

The specific objectives of PURE are:

- to develop a decision tool to assess benefits and costs for different site-specific remedial scenarios;
- to develop new, more effective methods to characterise a site and follow the efficacy of the remedial action. This will be based on new biosensors (using soil relevant bacteria) supported by field-based analytical techniques (novel sample preparation and immunoassay procedures) novel fuzzy areal site assessment for data analysis and improved modelling of the movement of the groundwater plume;
- to develop new techniques to remediate complex contaminated sites: anaerobic-aerobic treatment for simultaneous organohalogen abatement and to render heavy metals inert: electrobioremediation of mixed organic pollutants: coupled degradation of BTEX and organohalogens (the former acting as electron donors and the latter as electron acceptors): simultaneous remediation of saturated and unsaturated zones by thermally enhanced soil vapour extraction and co-solvent flooding: remediation of organohalogen polluted groundwater through co-metabolism with methane butane oxidisers;
- to integrate developed knowledge/ test experience into a report containing guidelines applicable to a large number of industrial sites in the EU.

Expected impacts

For European industry as a whole, PURE is a great opportunity to develop a consistent EU knowledge base in the field of soil and groundwater treatment, thus reducing the dependence on US proprietary technologies.

Quantifiable advantages are a >20% cost saving in site characterisation and monitoring, and the availability of alternative remedial technologies to replace the traditional digging and landfilling approach, yielding an anticipated 30 – 60% reduction in remediation costs. European citizens will benefit from the broadly applicable PURE deliverables as follows:

- directly, through the improved soil and groundwater quality made possible by the new technologies and because of the increased competitiveness of the service provider;
- indirectly, due to a better allocation of resources, by reducing the resources necessary for the clean-up of pollution sources. This will free funds to be spent elsewhere, such as improving industry strength, employment and a higher standard of living.

EVK1-CT1999-00033

Development of technologies using the activity of sulphate and metal reducing bacteria (SMRB) to remove heavy metals and metalloids from groundwaters and soils (METALBIOREDUCTION)

Problems to be solved

The presence of toxic heavy metals and metalloids (HMM) in the environment greatly affects the quality of water and food-chain. In contrast to most organic pollutants, HMM are never degraded. The aim of the present proposal is to develop a number of bioprocesses, based on the activity of sulphate and metal reducing bacteria (SMRB), to prevent HMM pollution of water bodies by assessing and minimising HMM pollution originating from contaminated sites. The possibility of treating metal-contaminated waters efficiently and economically will contribute to meeting one of the major demands of European citizens, namely the provision of affordable high quality water, while maintaining the integrity of ecosystems.

Scientific objectives and approach

More precisely, the proposal objectives are: (1) to obtain improved biological tools (bacteria and enzymes); and (2) to develop new cost-effective and reliable technological alternatives for removing HMM from groundwaters and soils. In order to achieve the above mentioned project objectives, the technical work consists of the following four main tasks:

- improved biological tools for metal and sulphate reduction. This work will include the selection of sulphate and metal reducing bacterial stains (SMRB) and the improvement of cytochrome efficiency;
- monitoring of biological processes. New biocaptors with whole cells or enzymes (cytochromes) will be built and used to monitor bioavailable metal content, and new methods will be developed to analyse the bacterial communities;
- development of methods for the treatment of HMM pollutants in groundwaters and soils. Direct and indirect reduction of the HMM with the SMRB will be exploited at laboratory-scale in order to propose specific remedial strategies for each particular and actual contamination problem. The direct reduction of HMM by SMRB will be applied to groundwaters using bioreactors (pump and treat) and also to soils after excavation, pulping or heaping, and inoculation (on-site leaching). The indirect reduction of HMM by sulphate-reducing bacteria will be applied to groundwaters using bioreactors (pump and treat). *In situ* active barriers will be used for soil pore waters;
- technical feasibility and economic assessment of the treatment of HMM in groundwaters and soils. Modelling and simulation of the retained processes will follow the setting up of *in situ* and on-site pilot operations.

Expected impacts

The present project proposes the development of processes more efficient and less expensive than classical methods to remove metals from contaminated water and soil. This purpose converges with the trends of the new

Water Framework Directive, setting the objectives for water protection well into the century. Direct and indirect mechanisms of metal reduction by SMRB should produce high quality water. From an economic point of view, the development of better methods to treat waters and polluted soils will help to reinforce the technological independence of Europe. For the companies and particularly SMEs specialised in soil and water treatment, the project will introduce new products and open new markets.

EVK1-CT1999-00035

Long-term performance of permeable reactive barriers used for the remediation of contaminated groundwater (PEREBAR)

Problems to be solved

Contaminated land, landfills and sediments pose a serious environmental threat by polluting groundwater in the surrounding area. In 14 European countries contamination caused by uranium represents a particularly serious danger where drinking water resources might be affected. Other heavy metals and organic pollutants can also have a strongly deleterious effect on groundwater. Available technologies (e.g. pump and treat) fall short of solving the problem because their performance is not yet adequate for effective remediation. Permeable reactive barriers (PRB) represent a promising innovative technology for passive *in situ* groundwater remediation. Little is known, however, about the long-term behaviour (formation of coatings and precipitates, reduction of permeability) of PRB systems.

Scientific objectives and approach

The aim of the project is to elaborate the scientific basis for, laboratory and pilot-scale testing of and the practical application of a considerably more efficient and cost-effective *in situ* reactive barrier technology targeting groundwater contaminants. The general objective is to evaluate and enhance the long-term performance of PRB systems, especially of those targeting heavy metals and organic contaminants using sorption and/or precipitation mechanisms. The approaches taken to meet the project objectives will be the characterisation of different reactive materials and relevant attenuation processes in the reactive matrix of the PRB and their long-term behaviour. Technological methods to enhance the long-term efficacy and cost-effectiveness of the PRB system will be developed and tested under realistic conditions. The primary model test site will be an area in southern Hungary contaminated by uranium mining – thus including a region which is due to become part of the EU.

Expected impacts

The results of this project are expected to play a major role in establishing the permeable reactive barrier technology as an accepted, reliable and cost-effective method for the remediation of contaminated groundwater. The broad spectrum of activities within the proposal offers considerable utilisation opportunities. The investigation of potentially suitable reactive materials for specific target contaminants and the clarification of attenuation processes and ageing mechanisms will enable the optimisation of reaction conditions and barrier design. New technological developments such as specially tailored contaminant-targeting ligands and electrokinetic enhancement are aimed at improving the effectiveness of the groundwater cleaning task of PRB systems. The anticipated spread in the application of PRB systems will also necessitate regulation. As far as we are aware, the Federal Institute for Materials Research and Testing (BAM) in Berlin is currently the only regulatory body in Europe in a position to develop guidelines and regulations on reactive barriers. The project will develop a schematic, long-term effectiveness assessment method for lifetime prediction. The results of the project will therefore also influence the future sanctioning practice of such remediation systems by the responsible authorities.

EVK1-CT1999-00036

Programme for the prevention of diffuse water pollution with phosphorus from degraded and re-wetted peat soils (PROWATER)

Problems to be solved

The re-wetting and restoration of peatlands (synonym: histosols) can be accompanied by the mobilisation of phosphorus (P), its transport to adjoining aquatic ecosystems, an accelerated eutrophication and deterioration of water quality. PROWATER is aimed to develop scientifically based guidelines for the use and restoration of histosols that prevent the diffuse pollution of water with P. It contributes to the Community agricultural, environmental and, especially, water policies.

Scientific objectives and approach

The main objective of the project is to protect freshwater from diffuse pollution with P mobilised from histosols. Specific objectives are to: (1) identify the chemical forms of P in native, degraded and re-wetted histosols; (2) measure and assess the actual P pollution of ground and surface water in six representative field studies; (3) develop models which describe the main factors of P mobilisation and transport from histosols to water and calculate scenarios for re-wetting strategies; and (4) to develop a user-friendly DSS to enable re-wetting strategies at minimised P input to freshwater. PROWATER is organised in four connected work packages (WPs). In WP 1, the study areas in Israel, Germany, Poland, Sweden and in the UK will be characterised, equipped with automated field stations, and a co-ordinated field research and sampling programme will be carried out. In WP 2, the PO status of soils will be characterised by advanced analytical methods (total P.P forms by sequential fractionation, nuclear magnetic resonance and mass spectrometry, and desorption isotherms). The relationships between external factors and P mobilisation will be quantified in microcosm experiments under controlled conditions. The data sets will be used in WP 3 as model input. The quantified relationships between P status, external factors and P mobilisation will improve conceptual models of P transformations in histosols. Further-

more we will test, validate and adapt existing numerical methods of P mobilisation and transport. Reliable scenarios of re-wetting strategies will be simulated and the effects on diffuse P transfer from histosols to freshwater will be calculated. In WP.4 a DSS for histosol restoration and sustaining of good water quality will be developed. This requires the integration of scenarios from WP 3 with the ecological, political and socio-economic targets in study areas, participating countries and the EU. PROWATER will finish with the application and evaluation of the DSS in case studies of the consequences of re-wetting measures for end-users and stakeholders.

Expected impacts

We expect: (1) a database from field research on factors that control P mobilisation in rewetted histosols; (2) basic new evidence for the chemistry of P in histosols; (3) models on P mobilisation and transport and re-wetting scenarios; and (4) a DSS which is tested with local end-users and stakeholders to provide a basis for the implementation of re-wetting guidelines for the restoration of wetlands. The main environmental and socio-economic impact lies in the improvement of surface water quality, the preservation of agricultural land use in sensitive areas and its development towards landscape conservation, which can be an important income factor in some areas.

EVK1-CT1999-00042

In situ monitoring of landfill related contaminants in soil and water by infrared sensing (IMSIS)

Problems to be solved

The project will contribute to the abatement of water pollution from contaminated lands, landfills and sediments. With its capacity of on-line and real-time measurements of pollutants, measurement techniques which are not available at the moment, the proposed sensor is a valuable tool for landfill monitoring, risk assessment and control of remediation efficiency. It can, for example, improve the 'use' of natural attenuation techniques as a remediation technique. Natural attenuation, i.e. leaving remediation to natural processes without applying costly techniques, is based on the observation that there is a decrease in contaminant concentrations which limits the extent of the contaminant plume. The key disadvantage of natural attenuation is the need to ensure that the contaminant does not propagate further. The proposed sensors, placed in the vicinity of the plume may serve as a cost-effective and reliable alert network. Possible emerging economic possibilities for waste disposal should strengthen EU industrial competitiveness. This is of special importance for the EU with its densely populated production sites.

Scientific objectives and approach

The project aims at monitoring of soil and water for landfill related contamination by an *in situ* monitoring for soil and water by infrared sensing. A portable and rugged system will be developed that will allow sensor elements to be inserted and left in soil locations under the ground for long-term monitoring of organic pollutants. The concept of a buried sensor gives the opportunity to continuously monitor organic pollutants without sampling errors. Since it is important to monitor pollutants over a long period of time the sensor system will be optimised with regard to long-term stability.

Expected impacts

The IMSIS sensor concept is novel for landfill monitoring; its central objective is to open new possibilities for continuous monitoring and control. For this reason one objective of the project is to investigate and evaluate the need of end users with respect to sensor applications. Mid IR spectroscopic measurements are widely used for the analysis of samples placed inside spectrometers. This project is involved in the development and use of IR optical fibres for absorption measurement on remote locations. The development of this remote spectroscopy is on one hand an innovation with respect to real time analytical measurements inside landfills, on the other hand it opens the field for all kinds of IR remote sensing applications, e.g. in process control or measurements in explosion endangered environments.

Within the project, there will be a development of short segments of tapered and flattened fibres, which will serve as sensor elements in the sensor head. Tapering of fibres to increase sensitivity is a well-known technique in the UV and visible wavelength range. Tapering of MIR fibres is a completely new and demanding task since IR transmitting materials are difficult to process. A further improvement in sensitivity can be achieved by replacing tapered fibres by planar MIR waveguides with a thickness of a few micrometres. Such devices are at present not commercially available and will be taken into consideration.