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NATO/CCMS Pilot Study

Evaluation of Demonstrated and Emerging Technologies for the Treatment of Contaminated Land and Groundwater (Phase III)

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Annual Report
NATO/CCMS Pilot Study

Evaluation of Demonstrated and Emerging Technologies for the Treatment and Clean Up of Contaminated Land and Groundwater (Phase III)

Vienna, Austria
February 23-27, 1998

May 1998

NOTICE

This report was prepared under the auspices of the North Atlantic Treaty Organization's Committee on the Challenges of Modern Society (NATO/CCMS) as a service to the technical community by the United States Environmental Protection Agency (U.S. EPA). The document was funded by U.S. EPA's Technology Innovation Office under the direction of Michael Kosakowski. The Annual Report was edited and produced by Environmental Management Support, Inc., of Silver Spring, Maryland, under U.S. EPA contract 68-W6-0014. Mention of trade names or specific applications does not imply endorsement or acceptance by U.S. EPA.

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INTRODUCTION

The Council of the North Atlantic Treaty Organization (NATO) established the Committee on the Challenges of Modern Society (CCMS) in 1969. CCMS was charged with developing meaningful programs to share information among countries on environmental and societal issues that complement other international endeavors and to provide leadership in solving specific problems of the human environment. A fundamental precept of CCMS involves the transfer of technological and scientific solutions among nations with similar environmental challenges.

The management of contaminated land and groundwater is a universal problem among industrialized countries, requiring the use of existing, emerging, innovative, and cost-effective technologies. This document provides a report from the first meeting of the Phase III Pilot Study and is designed to share information among countries on innovative treatment technologies. The United States is the lead country for the Pilot Study, and Germany and The Netherlands are the Co-Pilot countries. The first phase successfully concluded in 1991, and the results were published in three volumes. The second phase, which expanded to include newly emerging technologies, concluded in 1997; final reports documenting 52 completed projects and the participation of 14 countries will be published early in 1998. Through these pilot studies, critical technical information has been made available to participating countries and the world community.

The Phase III study focuses on the technical approaches for addressing the treatment of contaminated land and groundwater. This Phase will address issues of sustainability, environmental merit, and cost-effectiveness, in addition to continued emphasis on emerging remediation technologies. The objectives of the study are to critically evaluate technologies, promote the appropriate use of technologies, use information technology systems to disseminate the products, and to foster innovative thinking in the area of contaminated land. The Phase III Mission Statement is provided at the end of this report.

The first meeting of the Phase III Pilot Study on the Evaluation of Demonstrated and Emerging Technologies for the Treatment and Clean Up of Contaminated Land and Groundwater convened in Vienna, Austria, on February 23-27, 1998, with representatives of 20 countries attending. Each participating country presents case studies or projects to the Pilot Study. At each meeting, these case studies are discussed and commented on by experts. At this meeting, 15 projects were selected for consideration by participating countries. Also, at this meeting, a special technical session was convened on treatment walls and related permeable reactive barrier technologies. The proceedings of that special session are available in a companion publication. Natural attenuation will be the specialty topic for the 1999 meeting.

This publication represents the first Annual Report of the Phase III Study. It contains abstracts of the first 15 remediation technology projects selected, reports on the legislative, regulatory, programmatic, and research issues related to contaminated land in each participating country, and the statement of purpose for the Phase III Pilot Study. General information on the NATO/CCMS Pilot Study may be obtained from the Country Representatives listed at the end of this report, or—for each Pilot Study project—from the technical contacts identified in each abstract.

Stephen C. James
Walter W. Kovalick, Jr., Ph.D.
Co-Directors

PROJECTS INCLUDED IN NATO/CCMS PHASE III PILOT STUDY

PROJECT	COUNTRY	MEDIUM		CONTAMINANT					NOTES
		Soil	Groundwater	VOCs	SVOCs	Pesticides/PCBs	PHCs	Inorganics	
1. Bioremediation of Loamy Soils Contaminated with Hydrocarbons and Derivatives	Belgium	✓			✓		✓		PAHs, munitions chemicals
2. Mercury-Contaminated Spolchemie Plant	Czech	✓	✓		✓			✓	Hg, metals, PAHs, TPH
3. Permeable Treatment Beds	Germany		✓	✓	✓		✓	✓	PAHs, BTEX, TCE, PCE
4. Rehabilitation of Land Contaminated by Heavy Metals	Greece	✓						✓	Pb, Zn, Cd, As, H^+, $SO_4^=$
5. Application of BioWalls/ BioScreens	Netherlands		✓	✓	✓	✓	✓		Chlorinated pesticides, BTEX, TPH, HCH, PCE, TCE
6. Rehabilitation of a Site Contaminated by PAH Using Bio-Slurry Technique	Sweden	✓			✓			✓	PAHs, cyanides, metals, ammonium compounds
7. Risk Assessment for a Diesel-Fuel Contaminated Aquifer Based on Mass Flow Analysis During the Course of Remediation	Switzerland		✓				✓		PHC
8. Obstruction of Expansion of a Heavy Metal/Radionuclide Plume Around a Contaminated Site by Means of Natural Barriers Composed of Sorbent Layers	Turkey	✓	✓					✓	Pb, As, Cr, Cu, Cd, Hg, Ni, Zn; ^{137}Cs, ^{90}Sr, ^{238}U
9. Solidification/Stabilization of Hazardous Wastes	Turkey	✓			✓	✓		✓	PCBs, AOX, metals
10. Metals Biofilms Interactions in Sulfate-Reducing Bacterial Systems	UK		✓					✓	Metals (Cu, Zn, Cd), radionuclides (Lab-scale)
11. Predicting the Potential for Natural Attenuation of Organic Contaminants in Groundwater	UK		✓	✓	✓		✓	✓	Coal tars, phenols, creosol, xylenols, BTEX, NH_4^+
12. Treatability of Enhanced *In Situ* Anaerobic Dechlorination	USA		✓	✓	✓				TCE, DCE, VC, PCE
13. Permeable Reactive Barriers for *In Situ* Treatment of Chlorinated Solvents	USA		✓	✓				✓	PCE, TCE, DCE
14. Dynamic Underground Stripping	USA	✓	✓		✓				PAHs, PCP
15. Phytoremediation of Chlorinated Solvents	USA		✓	✓					TCE, TCA, DCE, PCE, xylene, methyl cloride, TMB

KEY:

AOX = adsorptive organic halogens
BTEX = benzene, toluene, ethylbenzene, and xylenes
DCE = dichloroethene
HCH = hexachlorocyclohexane
PAHs = polycyclic aromatic hydrocarbons
PCBs = polychlorinated biphenyls
PCE = tetrachloroethene
PCP = pentachlorophenol
PHCs = petroleum hydrocarbons
SVOCs = semivolatile organic compounds
TMB = trimethylbenzene
TCA = trichloroethane
TCE = trichloroethene
VC = vinyl chloride
VOCs = volatile organic compounds

<table>
<tr><td colspan="4">Project No. 1
Bioremediation of Loamy Soils Contaminated With Hydrocarbons and Derivatives</td></tr>
<tr><td>Location
Former fuel depot “Site van Oss”
Belgium</td><td>Project Status
New</td><td>Media
Groundwater</td><td>Technology Type
In situ
Bioremediation</td></tr>
<tr><td rowspan="2">Technical Contact
Dr. Walter Mondt
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Prof. M. Penninckx
Université Libre de Bruxelles
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1180 Brussels, Belgium
tel. 32/(0)2.373.33.03
fax 32/(0)2.373.31.74</td><td>Project Dates
1997 - 2001</td><td colspan="2">Contaminants
Hydrocarbons and derivatives</td></tr>
<tr><td>Costs Documented?
Yes</td><td>Project Size
Pilot scale</td><td>Results Available?
Yes</td></tr>
</table>

1. INTRODUCTION

The current pilot project is proposed by the private partner Ecorem nv and the University of Brussels). The main objective of the project is the evaluation of the effectiveness of several bioremediation techniques for cleaning up loamy soils contaminated with hydrocarbons.

Bioremediation is currently used in numerous cases, nevertheless the present project is innovative because:

- most studies on bioremediation are focused on sandy soils, whereas this project will deal with loamy soils. Loamy soils account for a lot of polluted sites in Europe, but they present inherent difficulties for gas and solutes diffusion, which may hamper the processes of bioremediation;

- for each case to be treated, the relative performance of several bioremediation procedures will be compared;

- the inventory of the microflora of the polluted sites will use the recent procedures of molecular biology. This approach will result in a more objective picture of the microbial diversity of polluted sites, and will allow the definition of optimal nutrients “cocktails” for boosting the degradation properties of the microflora.

To date, the soil cleaning scenarios in Belgium have been mainly oriented towards selectively excavating and removing the pollution, to be dumped in Flanders or Wallonia in waste depots. This results in very high dumping costs and environmental taxes. Therefore it is important to develop a concept of soil cleaning so that the transport of polluted material across regional borders is kept to a minimum.

For all these reasons, and in line with the BATNEEC principle, the current pilot project is of great importance for all European countries dealing with cleaning problems of loamy soils and severe waste policy. The use of bioremediation techniques, both *ex situ* and *in situ*, meets this objective.

2. SITE DESCRIPTION

The necessary *in situ* and *ex situ* experiments and assays with regard to the current pilot project shall take place at the future soil recycling plant of Ecoterres s.a. in Brussels. The SDRB (Brussels Regional Development Co) is owner of the grounds where the pilot installations are planned and lets the site to Ecoterres s.a.

The plant will be constructed on the grounds of a former fuel depot “Site van Oss.” The soil was heavily polluted and recently cleaned, so that the construction of the plant can take place. A part of the plant will be reserved for the pilot project and all required technical support will be given by Ecoterres s.a.

3. DESCRIPTION OF THE PROCESS

In order to be able to dimension and adapt the new technologies with regard to the current pilot project, a research project is proposed, consisting of two main parts:

- *Preparatory activities* will characterize the contaminated soil, measure the microbial activity, and determine the maximum potential biodegradability of the pollutants present (this phase will result in an overview of the potential applicability of bioremediation as a cleaning technology for the various types of pollutants).

- *Pilot project*—various alternatives will be developed on a laboratory-scale using soil column studies. In order to get a realistic impression of the processes, one or more configurations will be developed on a larger scale.

On the basis of the analysis results obtained from the first research phase, a number of cleaning strategies will be extended into a pilot installation for the purpose of being able to realistically evaluate the effectiveness of these processes. The execution of both phases will take approximately four years.

4. RESULTS AND EVALUATION

Results of laboratory experiments are not yet available. However, on the base of already executed and comparative studies, there is a general knowledge of the possible difficulties encountered by the application of the specific techniques, the efficiency of several systems and the operational parameters.

More specifically, the use of bioremediation techniques for cleaning up loamy soils has already proven its effectiveness on the “Site van Oss” itself—the prospective location of the soil recycling plant. Due to the former activities on the “Site van Oss” as a fuel depot, a strong contamination (mainly mineral oil) of both soil and groundwater was observed.

The remediation of the non saturated area on the “Site van Oss” was effected by excavation of the “hot spots” (mineral oil >5,000 ppm). The remaining soils, containing mineral oil concentrations up to 5,000 ppm, were bio-restored by means of *in situ* composting and bioventing. Therefore the soils were mixed with compost and wood chips, in order to ameliorate structural properties and to provide a nutrient source for indigenous micro-organisms. A bioventing unit was installed for maintaining aerobic conditions and to eliminate volatile compounds.

After remediation, the average residual concentration of mineral oil was lowered to 490 ppm, in comparison with the imposed norm of 900 ppm.

5. COSTS

The estimated costs of the project will mostly depend on manpower. The costs, including the site preparation, setup, measurements, equipment, laboratory experiments, are estimated at about 3.5 million/man/year. A working period of four years for two persons for the technical and scientific support, this will bring the total estimated cost of the project to about 28 million.

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<table>
<tr><td colspan="4">Project No. 2

Mercury Contamination, Spolchemie Plant</td></tr>
<tr><td>Location
Spolchemie Plant, Usti nad Labem, Czech Republic</td><td>Project Status</td><td>Contaminants
Mercury; chlorinated hydrocarbons, PAHs, TPH; heavy metals</td><td>Technology Type
To be determined following remedial investigations</td></tr>
<tr><td rowspan="2">Technical Contact
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Fax: +420 2 5721 1255
E-mail: m.booth@prg.kap.cz</td><td>Project Dates
Accepted 1998</td><td colspan="2">Media
Soil and Groundwater</td></tr>
<tr><td>Costs Documented?
No</td><td>Project Size
Full-Scale</td><td>Results Available?
No</td></tr>
</table>

1. INTRODUCTION

Although other sites in Central Europe are recognized as being contaminated with hazardous waste, the Spolchemie Plant belongs to one of the largest and the most hazardous waste contaminated sites in Central Europe. It is located in a large town with a population of 100,000 inhabitants and about 300 m from a hospital. The plant has a high density of industrial buildings and service lines. The site is predominantly contaminated by mercury. KAP, with considerable experience with site remediation has been contracted to undertake studies to remediate the Spolchemie Plant.

2. SITE DESCRIPTION

The Spolchemie Plant is located in the center of the town of Ústí nad Labem, which is about 110 km northwest of Prague, Czech Republic. A number of different industrial products and semifinished products are produced in the Spolchemie Plant. Production in Spolchemie commenced more than 140 years ago. Now, more than 450 raw materials and semifinished products are utilized for chemical production. There are about 30 main production units and each of them utilize a number of different technologies. The estimated number of employees is about 2,500, and the area of the plant is about 52 ha.

3. MERCURY CONTAMINATION

Mercury contamination has been detected in the area of the electrolytic unit where chlorine and sodium hydroxide (NaOH) are the main products of a sodium chloride (NaCl) electrolytic process. The mercury results from the electrolytic process, but is mostly reclaimed. The contaminated area of the electrolytic unit is about 200 x 200 m. Besides the mercury, other pollution has been detected on the facility, such as chlorinated hydrocarbons, aromatic hydrocarbons, and heavy metals.

The enormous mercury pollution of underlying soil is a result of long-term electrolytic treatment with little or no mitigation measures concerning environmental protection at the plant. Pure liquid mercury was also detected in the soil during drilling and sampling activities. Mercury, in this form, increases the risks even more (mercury evaporation to atmosphere, possible oxidation-reduction reactions, *etc.*). Mercury concentrations in the area of electrolytic unit reach are significant—the average concentration is 1,630 mg/kg, and the maximum concentration is 386,000 mg/kg.

The total amount of mercury in the soil to a depth of 15 m has been estimated to be about 100 tonnes. Together with soil, there are about 1,600,000 tonnes of hazardous material on the site. The real mercury content in the soil is probably higher because the sampling was not undertaken under the electrolytic unit due to technical reasons.

Mercury pollution was also detected in the groundwater, with a with maximum measured concentration of 1.6 mg/l. The strata underlying the electrolytic unit are sedimentary rocks of Tertiary and Quaternary age. These sediments are represented by brown clays with gravel and sand occasionally present. Loess loams were also encountered on the site. The site is covered by a fill with a thickness of 0.5-2 m. A water-bearing formation is bound to porous layers of fluvial and deluvio-fluvial gravel and sand. The groundwater table is located at a depth from 0.5-12.5 m.

Mercury migrates in the soil along the preferential paths (cracks and large pores). The higher the porosity, the lower the retardation, and mercury can thus migrate in to deeper soil layers. High mercury concentration (in thousands of mg/kg) were also identified at depths of 15-20 m.

The Bílina River and Klíšský Creek represent the local drainage base for the Spolchemie site. Consequently, all pollutants that were not sorbed onto soil grains or degraded migrate to both the river and the creek. Eventually, they will migrate to the Labe River, which is in the vicinity of the site (0.6 km away) and represents the general drainage basin.

4. SERVICE DESCRIPTION AND STUDIES CONDUCTED AT SPOLCHEMIE PLANT

4.1. Service Description

4.1.1 Site Investigation

Hydrogeological investigations for soil and groundwater contamination are one of KAP's key activities. The primary goal of these investigations is to identify the type and extent of contamination present, as well as to document the geological and hydrogeological conditions at a given site. KAP provides this service in accordance with current Czech legislation, but regularly works to Western European and North American standards for clients when required. KAP's professionals efficiently perform all aspects of a project, including the technical works. Since its foundation, KAP has completed several hundred of these investigations throughout the country, establishing a reputation for consistently providing top-quality, cost-effective studies.

4.1.2 Site Risk Assessment

Risk assessments examine and evaluate the risks from all types of pollution to the natural environment and the surrounding population. Such an analysis includes an assessment of the environmental contaminants that are present or which are likely to appear, the potential receptors of these contaminants (from populations to ecosystems), and the pathways that the contaminants might take to reach these receptors (*e.g.*, through soil, air, water, or food). A risk assessment can be used, for example, to identify the potential risks to human health and the environment arising from a company's activities. The basic steps in such a risk assessment are:

- Hazard identification
- Pathway identification
- Target/receptor definition
- Exposure Assessment
- Risk characterization
- Preliminary remediation feasibility study

4.1.3 Site Remediation Feasibility Studies

KAP professionals recognize that when identifying an appropriate site remediation program, many parties have a stake in the selection. These parties represent the local community, industry (senior management of the plant), environmentalists, scientific and engineering professionals, and the government. Their concerns differ, as do their values. They will inevitably disagree about what is the best remedy and even as to what level of protection is needed. In addition, technical reasons (*i.e.*, site conditions, number of remedial techniques that exist, *etc.*) further increase the difficulty of remedy selection. KAP has defined a system for conducting "Site Remediation Feasibility Studies" at all its sites. The system is conducted in a step by step manner (re-evaluation of each step can be conducted as necessary):

1. Define Problem (Establish what is the Hazard on the Site).
2. Establish Objectives (Defined in Site Risk Assessment Study).
3. Develop Alternatives (Technology Suitable for the Site In Question).
4. Analysis of Alternatives.
5. Implement and Monitor.

4.2 Studies Conducted at Spolchemie Plant

4.2.1 Spolchemie Site Investigation and Risk Assessment, 1995

KAP performed a Site Investigation and a Risk Assessment for the Spolchemie Plant in 1995. Both studies focused on the entire plant and its vicinity. During the site investigation, 100 shallow probes (to a depth of 1.0 m below the surface) and 38 boreholes (to a depth of 6-20 m) were drilled. A sampling and analyses program was conducted:

Sampling Activity	Number of Samples
Soil Gas	138
Soil	138
Groundwater	59
Surface Water	10

Ref: KAP, Spolchemie Site Investigation, 1995

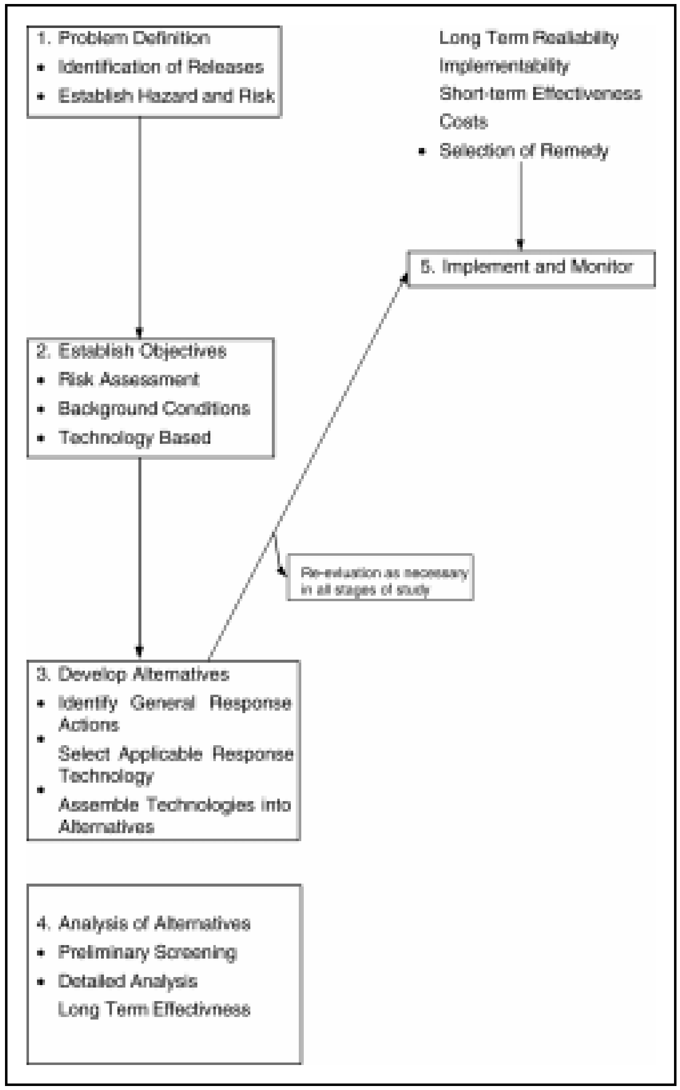
Sampling and analyses found that the Spolchemie Facility is contaminated with chlorinated hydrocarbons, aromatic hydrocarbons, petroleum hydrocarbons, and heavy metals. Following the Site Investigation, a Site Risk Assessment was carried out, and the target limits for the site remediation program were defined. Mercury was identified as the most hazardous pollutant on the site because of its extremely high measured concentrations in the area of electrolytic unit.

4.2.2 Spolchemie Complimentary Site Investigation and Risk Assessment, 1996

KAP, recognizing that the electrolytic unit was the main source of mercury contamination in the plant, conducted a complementary Site Investigation Risk Assessment in 1996 focusing on the area surrounding the electrolytic unit. Drilling activities, mercurometry, and sampling were performed during the course of both studies. The pollution in the area was defined more specifically, and potential pollutant migration pathways were evaluated. The direction of contaminant transport were defined and potential risk for particular pollutants were stated.

4.2.3 Spolchemie Feasibility Study For Site Remediation Program, 1997-ongoing

Based on the results from the Site Investigation and Risk Assessments mentioned above, KAP is currently conducting a Feasibility Study for the site remediation. The Feasibility Study will take into account that any proposed remediation program will be implemented while the plant is in operation. Simultaneously with the Feasibility Study, a cost-benefit study has been carried out. The Feasibility Study will assess all site remediation techniques with respect to all possible site limitation factors, including: intended construction activities on the plant; possible demolition of buildings and other objects; electrolytic unit operation; legislative conditions and restrictions; and values of reclaimed sources. The complete model for the Spolchemie Feasibility Study Site Remediation Program is shown in the figure.



Project No. 3 **Permeable Treatment Beds**			
Location Former solvent blending plant, Essen, Germany	**Project Status** Interim Report, field tests finalized	**Media** Groundwater	**Technology Type** Permeable Reactive Barrier
Technical Contact Eberhard Beitinger WCI Umwelttechnik GmbH Sophie-Charlotten-Straße 33 14059 Berlin tel: +49-/0)30-32609481 fax: +49-(0)30-32609472 E-mail: exbeiti0@wcc.com	**Project Dates** Accepted 1997	**Contaminants** Chlorinated and nonchlorinated solvents, BTEX-aromates, TCE, PCE, PAHs	
	Costs Documented? Only cost estimates available	**Project Size** Full-scale	**Results Available?** Field test results available

1. INTRODUCTION

This on-site remedial demonstration project will be conducted at an old solvent blending plant in the suburbs of the city of Essen. The downstream plume of heavily contaminated groundwater will be treated by an innovative permeable reactive barrier (PRB) technology. A full-scale field test was conducted to evaluate the adsorption capacity of the filling material (activated carbon) and the performance time of a single filling. Project objectives are to learn about implementation of the wall structure and long term efficiency of the fillings regarding in-situ treatability of groundwater by passing the barrier.

2. BACKGROUND/SITE DESCRIPTION

From 1952 to 1985, a chemical factory was situated on an area of about 10,000 m² located in a city in the Ruhr area. Mostly solvents like hydrocarbons, volatile chlorinated hydrocarbons, PAHs, petroleum, turpentine oil substitute, ketones, monoethylene glycol, and alcohols were handled, stored, and processed. Today, a residential building is left on the site, while underground and above ground tanks were demolished.

The ground was backfilled 2.0 m over silty soil (approximately 4-11 m thick). Below the silt, a layer of sand and gravel (0.8-7.4 m) and marly sands (7.0-16.3 m deep) have been detected. The marly sands are the first waterproof layer.

The first aquifer is about 1.0-3.2 m thick, and the flow velocity is very slow. The following coefficients of permeability exist:

- first aquifer: $k_f = 6.6 \cdot 10^{-6}$ m/s
- waterproof layer: $k_f = < 10^{-7}$ m/s

A groundwater spring emerges north of the site; due to this, the surface water in a small creek downstream the source is contaminated. The main contaminant concentrations in groundwater are petroleum hydrocarbons (23.6-164.0 mg/l), volatile chlorinated hydrocarbons (27.0 mg/l), and aromatic hydrocarbons (153.0 mg/l). Furthermore, high concentrations of manganese and iron are present.

The project is funded by the city of Essen and the state Nordrhein-Westfalen, as the former owner went bankrupt.

3. DESCRIPTION OF THE PROCESS

Three alternatives of permeable treatment wall types have been developed and evaluated by WCI for specific site conditions. Regarding construction costs, treatment efficiency and groundwater control, “Alternative 2” has been evaluated as best. This alternative consists of a short treatment wall section of 35 m length with additional vertical barriers along the two endings of the treatment bed. The total width of the plume to approximately 145 m is covered. The groundwater will be directed to the treatment section, and contaminants will be recovered by adsorption.

A PRB is a passive *in situ* treatment zone of reactive material that degrades or immobilizes contaminants as groundwater flows through it. Natural gradients transport contaminants through strategically placed treatment media. The media degrade, sorb, precipitate, or remove dissolved organics, metals, radionuclides, and other pollutants.

WCI-Umwelttechnik GmbH, the German subsidiary of Woodward-Clyde, has developed and patented a barrier construction system that allows the removal of used reactive material and the refill of fresh media without destroying or rebuilding the wall system. This design will enable potential users to operate the treatment barrier for several decades without severe reduction of effectiveness. The permeable wall construction can be installed in open trenches down to 10 or more meters. The system includes filter layers to prevent losses of hydraulic capacity by fine soil particles, and a permanent open space for the reactive material, as well as measures to control effectiveness and monitor the groundwater quality.

In comparison with pump-and treat methods to clean groundwater contaminations, the passive PRB concept is technically sound and, in most cases, less expensive to install. Operational costs are very low and limited to monitoring, since no pumping of groundwater is necessary.

4. RESULTS AND EVALUATION

Installation of the PRB will be started in 1998, and performance evaluation will be executed in the following years by monitoring groundwater qualities and the remaining adsorption capacities of the filling material. The results of the field testing with two carbon filter columns was conducted successfully in the second half of 1997. Both columns were operated under *in situ* conditions regarding groundwater quality and contaminant concentrations. No problems with fines or precipitating iron or manganese have been detected during a five-month operation period. One column was operated during actual time conditions, and the second with a much faster scale (1 month simulating 25 years of operation). The calculated operation time of one filling was a minimum of 30 years. Test results showed performance times up to 5 times longer. Also, no negative effects by biological activity such as bio-clogging could be detected during the field testing.

These results will be presented to the relevant water authorities for their permit review. After the permit process is finalized, the construction of the full-scale PRB will be started immediately.

5. COSTS

The costs for conducting the field tests have been DM 100,000. The overall costs to erect the wall system and the fill with activated carbon is estimated to be DM 1,500,000. Included are additional costs for monitoring the water quality for 30 years, which is as long as the minimum performance time of one single filling will be.

In comparison with traditional pump-and-treat groundwater remediation costs, the proposed permeable reactive barrier system will be at least 25 percent less expensive.

6. REFERENCES

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2. Eberhard Beitinger, and Eckard Bütow. *Abschlussbericht zur Durchführung von Pilotversuchen für eine geplante Adsorberwand - „Schönebecker Schlucht" in Essen*, Internal Report, WCI, Wennigsen, 1998 (not published).

<table>
<tr><td colspan="4">Project No. 4
Rehabilitation of Land Contaminated by Heavy Metals</td></tr>
<tr><td>Location
Lavrion, Kassandra (Greece)
Sardinia (Italy)
Estarreja (Portugal)
Burgas (Bulgaria)
Baia, Navodari, (Romania)</td><td>Project Status
1st Progress Report</td><td>Media
Mining Tailings, Soil</td><td>Technology Type
Alkaline additives
soil leaching
chemical fixation-immobilization</td></tr>
<tr><td rowspan="2">Technical Contact
Prof. A. Kontopoulos
National Technical University of Athens,
GR-157 80 Zografos,
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fax: +30-1-7722168
E-mail: kontop@metal.ntua.gr</td><td>Project Dates
Accepted 1998
Final Report 2002</td><td colspan="2">Contaminants
Lead, zinc, cadmium, arsenic, acidity, sulfates</td></tr>
<tr><td>Costs Documented?
Alkaline additives: YES
Soil leaching, chemical fixation-stabilization: NO</td><td>Project Size
Laboratory,
Demonstration-scale,
Full-scale</td><td>Results Available?
Yes</td></tr>
</table>

1. INTRODUCTION

The Project objectives are to develop innovative and cost-effective technologies for the environmental rehabilitation in polymetallic sulfide mining and processing operations. These industrial activities often result in the generation of millions of tones of wastes and tailings that are characterized as toxic and hazardous. Improper environmental management practiced in the past, and, to a lesser degree in current operations as well, has resulted in extensive, in spatial terms, and intensive, in terms of concentrations, contamination of land and groundwater. Almost all of polymetallic sulfide mines in Europe are now redundant; however the mining works and tailings remain active pollution sources for decades or even centuries after mine closure. The Project aims at developing an integrated management scheme involving neutralizing the active sources of pollution and cleaning-up or stabilization of the contaminated land and groundwater.

Technologies under development include:

- Control of acid generation and migration from sulfidic tailings by preventive, containment and remedial technologies
- Rehabilitation of land contaminated by heavy metals by chemical immobilization techniques
- Rehabilitation of land contaminated by heavy metals by integrated leaching techniques

The Project is funded by the European Commission (LIFE, BRITE-EURAM, ENVIRONMENT AND CLIMATE and INCO-COPERNICUS Programmes), by a number of Industries and one Consulting firm. Total cost for research and development is 3,000,000 ECU over the period 1993-2001.

The status of the technologies is bench and demonstration-scale. One particular technology has been applied in full-scale (Rehabilitation of a 150,000 t/2,500 ha sulfidic tailings dam in Lavrion, using ground limestone as an inhibitor for the acid-generating reactions).

2. SITES

The project aims at developing technologies of a generic nature applicable to all polymetallic sulfide mining operations. The following sites are being included as case studies:

- Lavrion mines, Greece. Redundant galena-sphalerite-pyrite mines. Extensive sulfidic and oxidic tailings act as active pollution sources. The land has been heavily contaminated by heavy metals over an area of 3x6 km.
- Kassandra mines, Greece. Active galena-sphalerite-auriferous pyrite mines. Interest is focused on the rehabilitation of the acid-generating waste rock dumps.
- Monteponi and Montevecchio mines, Sardinia, Italy. Redundant lead-zinc pyrite mines. Extensive flotation tailings dams and calamina leach residues (calamina red muds) constitute active sources of pollution that result in contamination of the surrounding land. Interest is focused on rehabilitation of the tailings dams and of the contaminated soils.
- Estarreja industrial site, Portugal. Extensive pyrite cinders from a sulfuric acid plant. Interest is on inhibiting the mobilization of heavy metals from the cinders.
- Burgas copper mines, Burgas, Bulgaria and Baia copper flotation plant, Romania.. Interest is focused on the rehabilitation of the extensive tailings dam that contains toxic and radioactive tailings. Also on the use of engineered wetlands as a passive treatment scheme for contaminated waters from the Burgas mine
- Navodari, Romania. An industrial plant producing sulfuric acid and superphosphates has generated extensive pyrite cinders and phosphogypsum tailings. A methodology for environmental rehabilitation is under development.

3. DESCRIPTION OF THE PROCESSES

Three processes are under development. The first aims at inhibiting acid generation and contaminant mobilization from sulfide tailings as a preventive measure against further pollution. The second is a remedial process for cleaning-up of contaminated land by removing the heavy metals using leaching techniques. The third is again a remedial process aiming at the *in situ* chemical immobilization of the heavy metals.

3.1 Inhibition of the acid generation from sulfidic tailings.

Acid generation from sulfidic tailings may be inhibited (a) by excluding contact of the tailings with either oxygen or water or both and (b) by inhibiting the acid-generating reactions:

(a) *Exclusion of contact with oxygen.* The method adopted is the application of a composite dry cover that includes a clay layer maintained in saturated condition at all times. Saturation inhibits diffusion of oxygen from the atmosphere to the tails and the clay layer acts as an effective oxygen transport barrier. The technique has been widely practiced in wet climates. Aim of this project is to develop a composite cover configuration that will maintain saturation in arid Mediterranean climates. Demo-scale application is under way.

(b) *Inhibition of the acid-generation reactions.* This is practiced by the addition of ground limestone to the acid-generating tailings so that the acid-generation reactions are impeded. Limestone additions at a rate stoichiometrically equivalent to the acid-generation capacity of the tails will effectively hinder acid generation. Aim of this project is to investigate the possibility of forming a hard pan within the tails by adding only 10-20% of the stoichiometrically required limestone. Other alkaline additives, such as fly ash, will also be tested. Bench- and demo-scale tests are being carried out. Full-scale rehabilitation of a flotation tailings dam in Lavrion (~2,500 ha, ~150,000 t of tails) has been done with limestone additions equal to the stoichiometric requirement.

3.2 Leaching methods for the clean-up of contaminated land

Integrated treatment flow-sheets are being developed on a bench-scale; pilot-plant applications will follow. They include the following unit operations: (a) Soil leaching, using acidic chloride solutions ($HCl+CaCl_2$) or organic complexing agents (citric acid, Na-EDTA, Ca-EDTA), (b) metals removal and recovery from the leach liquors in the form of a low-volume residue appropriate for controlled disposal or recycling, (c) regeneration and recycling of the leach solution, (d) final polishing of liquid effluents in order to become compatible with disposal regulations.

3.3 Chemical fixation-immobilization methods for the rehabilitation of contaminated land

Chemical stabilization of the heavy metals *in situ* in soils involves admixing with stabilizing agents that will transform the existing metal species to others of lower solubility-bioavailability and mobility. The process is under development in bench- and demonstration-scale experiments. A number of inorganic and organic wastes or low-cost materials are being tested as stabilizing agents, including: phosphates, fly ash, bentonite, cement kiln dust, biological sludge, compost, saw dust. The efficiency of stabilization during bench-scale experiments is examined by chemical extraction tests as well as by *in vivo* tests involving plant growth using *Phaseolus vulgaris starazagorski* as plant indicators. Demonstration-scale applications involve *in situ* rehabilitation of soil and development of an aesthetic vegetative cover by planting a mixture of 15 seeds.

4. RESULTS AND COSTS

4.1 Inhibition of acid generation from sulfide tailings

Full-scale rehabilitation of the flotation tailings dam in Lavrion proved to be quite successful; after two years, pore water improved from the initial value of pH 2.2 to pH 6.5 and is slowly rising. The cost of the application was (1996 prices) US$290,000 for an area of 2,500 ha or US$11.5 per m^2.

The other processes are still under development.

4.2 Leaching methods for the clean-up of contaminated land

Leaching is being applied to a highly contaminated soil from Lavrion with composition Pb 3.48%, Zn 2.02%, Cd 100 mg/kg, AS 2800 mg/kg, Ca 7.28%. Leaching with $CaCl_2$-HCl resulted in the removal of >90% of Pb, Zn and Cd. Citric acid and EDTA removed between 60-90% of the heavy metals. Reagent consumption was high because of the dissolution of calcium carbonate from the soil. Leaching with Ca-EDTA seems to overcome this problem. Removal of the heavy metals from the leach liquors is being studied with hydroxide and/or sulfide precipitation and reagent regeneration by resin treatment.

4.3 Chemical fixation methods for the rehabilitation of contaminated land.

Bench-scale stabilization experiments revealed that both the EPA-TCLP toxicity and the bioavailable fraction of Pb, Zn and Cd in soils can be drastically reduced by additions of fly ash, biological sludge and phosphates as stabilizing agents. However, *in vivo* experiments with indicator plants did not reveal any change in the metal uptake pattern of the plants from the stabilized soils. Phytomass production increased with the biological sludge additions, but decreased with fly ash and phosphate additions. The results are being evaluated in demo-scale applications in the “Neraki” site, Lavrion

5. COSTS

Not available.

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<table>
<tr><td colspan="4">Project No. 5

Application of Biowalls/Bioscreens</td></tr>
<tr><td>Location
Refinery, dry cleaner, chemical plant</td><td>Project Status
Initial report</td><td>Media
Groundwater</td><td>Technology Type
Bioscreens/biowalls</td></tr>
<tr><td rowspan="2">Technical Contact
Huub Rijnaarts
TNO Institute of Environmental Sciences, Energy Research and Process Innovation
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The Netherlands
tel: +31 55 5493380
fax: +31 55 5493410
E-mail: H.H.M.Rijnaarts@mep.tno.nl</td><td>Project Dates
Accepted 1998
Final Report 1999</td><td colspan="2">Contaminants
Oil, BTEX, chlorinated solvents, chlorinated pesticides, and benzene</td></tr>
<tr><td>Costs Documented?
Not yet</td><td>Project Size
Lab- and pilot-scale</td><td>Results Available?
End of 1998</td></tr>
</table>

1. INTRODUCTION

The objective of this demonstration is to develop and demonstrate the technical and economical feasibility of various biowall/bioscreen configurations for interception of mobile groundwater contaminants, as a more cost-effective and groundwater resources saving alternative for currently used pump-and-treat approaches.

2. SITE DESCRIPTIONS

Chlorinated solvent site. The Rademarkt Site (Groningen, The Netherlands) contaminated with perchloroethylene (PCE) and trichlorethylene (TCE), mixed redox conditions, *i.e.*, separate reducing and oxidizing zones. Transformation rates of especially vinyl chloride as observed in the field (and in the laboratory) are too slow to prevent migration of this hazardous compound to areas to be protected. Plume interception is therefore required.

Oil refinery site. At this oil refinery site in the Rotterdam Harbor area, it is required to manage a plume of the dissolved fraction of a mineral oil/gasoline contamination (80% of the compounds belong to the C6-C12 fraction).

Aromatic hydrocarbon (BTEX) sites. At three sites in the north part of the Netherlands, deep anaerobic aquifers contaminated with benzene, toluene, ethylbenzene or xylenes (BTEX) have been investigated. Under the existing sulfate-reducing conditions, the intrinsic biodegradation of toluene and ethylbenzene could be demonstrated in the field and in microcosm studies. Benzene was shown to be persistent. Managing the benzene plumes, *i.e.*, by enhanced *in situ* bioprocesses, is therefore required.

Chlorinated pesticides site. Hexachlorocyclohexane (HCH) isomers are important pollutants introduced by the production of lindane (gamma HCH). At the site of investigation, interception of the HCH/chloro-benzene/benzene plume is needed.

3. DESCRIPTION OF THE PROCESS

Chlorinated solvent site. Laboratory experiments identified that a mixture of electron-donors is most suitable to enhance the *in situ* reductive dechlorination. An *in situ* pilot test with an anaerobic activated zone designed for complete reductive dechlorination is planned this fall.

Oil refinery site. A reactive trench with a biosparging unit will be used. Bench scale experiments have been finished and established: i) optimal grain-size and packing density for the porous media used in the trench; and ii) optimal oxygen supply rates to sufficiently initiate aliphatic hydrocarbon biodegradation and to minimize clogging with iron(III)oxides.

Aromatic hydrocarbon (BTEX) sites. Microcosms were used to investigate possibilities to stimulate biodegradation of BTEX compounds. Especially, addition of nitrate and low amounts of oxygen to the anaerobic systems appears to be the appropriate way to create down-stream biostimulated zones. The laboratory results are currently used for designing pilot demonstration tests to be performed this summer/fall.

Chlorinated pesticide site. A bioactivated zone as an alternative to conventional large scale pump-and-treat is currently being investigated. At present, laboratory process research aimed at developing a combination of anaerobic-microaerophilic *in situ* stimulation in such a bioactivated zone is being performed.

4. RESULTS AND EVALUATION

The status of most projects is in bench-scale testing or in preparing a pilot-phase. First evaluations of technology performance are to be expected at the end of this year.

5. COSTS

In a separate cost-analyses project the costs of investment and operation of various bioscreen configurations (*i.e.*, the funnel-and-gate™, the reactive trench and the biostimulated zone configuration) is being evaluated for various sites. The results can be reported at end 1998/1999.

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Project No. 6

Rehabiliitation of a Site Contaminated by PAH Using Bio-Slurry Technique

Location	**Project Status**	**Media**	**Technology Type**
Former railroad unloading area, northern Sweden	Interim	Soil	*Ex situ* bioremediation
Technical Contact	**Project Dates**	**Contaminants**	
Erik Backlund Eko Tec AB Näsuddsvägen 1o 93221 Skelleftehamn Sweden tel: +46/910-33366 fax: +46/910-33375	Accepted 1996 Final Report 1999	coal tars, phenols, cyanides, metals, ammonium compounds	
E-mail: erik.backlund@ebox.tninet.se	**Costs Documented?** No	**Project Size** Full-scale (3,000 tons)	**Results Available?** Yes

1. INTRODUCTION

Eko Tec AB is a Swedish environmental engineering company dealing with problems posed by hazardous wastes, soil, and water pollution. Main clients are the oil industry, Swedish National Oil Stockpile Agency, and the Swedish State Railways.

In 1995, Eko Tec was contracted for bioslurry remediation of approximately 3,000 tons of creosote-contaminated soil and ditch sediments from a railway station area in the northern part of Sweden. A clean-up criterion of 50 ppm total-PAH was decided by the environmental authorities. For the specific PAH compounds benzo(a)pyrene and benzo(a)anthracene, a cleanup criterion of 10 ppm was decided.

Full-scale treatment has been preceded by bench- and pilot-scale treatability studies carried out at the Eko Tec treatment plant in Skelleftehamn, Sweden.

2. SITE DESCRIPTION

Not available

3. DESCRIPTION OF THE PROCESSS

3.1 Pretreatment

The contaminated soil was initially treated to reduce volume. Stones and boulders were separated from the rest of the soil. In the next step, the soil was screened in a 10 mm sieve. Soil with a grain size less than 10 mm was mixed with water and later pumped to wet-screening equipment, in which particles >2 mm were separated from the process. The remaining soil fraction (<2 mm) was pumped to a 60 m^3 slurry-phase bioreactor for further treatment. The volume of the treated soil fraction (<10 mm) was approximately 25 m^3. Samples were taken from the soil before water was added.

3.2 Slurry-Phase Bioreactor Treatment

Slurry-phase treatment was carried out in a 60 m^3 Biodyn reactor. During treatment, the soil/water mixture was continuously kept in suspension. In order to optimize the degradation rate, an enrichment culture containing microorganisms that feed on PAH was added to the slurry, together with nutrients and soil activators. During the treatment phase, dissolved oxygen, nutrient concentration, temperature, and pH were monitored continuously.

After 27 days of treatment, the cleanup criteria were met and the slurry-phase treatment process was closed. The slurry was pumped to a concrete basin where the treated soil was separated from the water by sedimentation. The waster was stored for reuse in the text treatment batch. The treated soil will be reused as fill material.

3.3 Monitoring Program

In order to determine the initial PAH concentration, a soil sample was taken from the soil fraction <10 mm. During the wet screening process, a soil sample was taken from the separated soil (<2 mm fraction). Samples were also taken from the slurry phase during treatment. Soil samples were stored by freezing, and then sent to the laboratory. The same accredited laboratory was used during the project period.

4. RESULTS

Cleanup criteria were met in 14 days. The initial PAH concentration (total PAH) was 219.9 ppm. Final concentration after 27 days of treatment was 26.97 ppm, which is well below the cleanup criterion of 50 ppm. PAH compounds benzo(a)pyrene and benzo(a)anthracene were occurring in concentrations below the cleanup criterion of 10 ppm.

5. COSTS

Not yet available

<table>
<tr><td colspan="4">Project No. 7
Risk Assessment for a Diesel-Fuel Contaminated Aquifer Based on Mass Flow Analysis During the Course of Remediation</td></tr>
<tr><td>Location
Menziken / Studen, Switzerland</td><td>Project Status
Interim</td><td>Media
Groundwater</td><td>Technology Type
In situ Bioremediation</td></tr>
<tr><td rowspan="2">Technical Contact
Mathias Schluep
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Ifangstrasse 11
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E-mail:
mathias.schluep@bmgeng.ch</td><td>Project Dates
Accepted 1997
Final Report 2000</td><td colspan="2">Contaminants
Petroleum hydrocarbons (diesel fuel, heating oil)</td></tr>
<tr><td>Costs Documented?
No</td><td>Project Size</td><td>Results Available?
Yes</td></tr>
</table>

1. INTRODUCTION

The studies are aimed to give a scientific basis for an evaluation procedure, allowing to predict the treatability of sites contaminated with petroleum hydrocarbons with in situ bioremediation technologies, such as biorestoration and intrinsic bioremediation [Schluep *et al.*, 1998]. This includes the description of the risk development with time by identifying critical mass flows. The focus of the project lies on the modeling of movement and fate of PHC in the subsurface.

2. SITE DESCRIPTION

At the *Menziken site* [Bregnard *et al.*, 1996; Hunkeler, 1997; Hunkeler *et al.*, 1995] the contaminated aquifer was remediated based on the stimulation of indigenous microbial populations by supplying oxidants and nutrients (biorestoration). Detailed investigations were made from 1988 until 1995. The engineered *in situ* bioremediation took place from 1991-1995.

At the *Studen site* [Bolliger *et al*., 1998] no engineered remedial actions were taken. The investigations started in 1993 and led to a better understanding of the biological processes occurring in the aquifer. It could be shown that intrinsic bioremediation is a major process in the removal of PHC at this site.

3. DESCRIPTION OF THE RESEARCH ACTIVITY

For the risk assessment two processes in PHC contaminated aquifers are of special interest. 1) Dissolution of soluble PHC from the oil phase into the mobile phase water, 2) Biodegradation of PHC, which mainly takes place in the water phase. Since both processes are slow under natural conditions and in most cases cannot be measured separately in the field, laboratory experiments were set up to study them.

4. RESULTS AND EVALUATION

Preliminary results of the laboratory studies were implemented in order to perform a risk assessment for the Menziken site in a diploma thesis at the Swiss Federal Institute of Technology ETH [Wyrsch and Zulauf, 1998]. The attenuation of some selected PHCs was calculated from the time when the spill occurred until the end of the corrective actions taken. Although some uncertainties about site specific data and model development remain, the results show good correlation with actual concentrations measured at the Menziken site [Wyrsch and Zulauf, 1998].

	Menziken	Studen
contamination	diesel fuel 10,000 - 12,000 lt	heating oil ~ 40,000 lt
initial remedial action	10 % recovered by pumping ~ 50 % removed by excavation	70 - 95 % recovered by pumping
in situ bioremediation	engineered (biorestoration)	intrinsic
period of bioremediation	1991-95	1993 - now
aquifer	glaciofluvial outwash deposits	glaciofluvial outwash deposits
water table	3 - 4 m below surface	2 - 4 m below surface
hydraulic conductivity	$4.5 \pm 2.5 \times 10^{-3}$ m s^{-1}	2×10^{-4} - 5×10^{-3} m s^{-1}
average flow velocity	4 - 6 m d^{-1}	~ 0.3 m d^{-1}
distance to the closest drinking water wells	70 m upstream 150 m downstream	1000 m upstream no well downstream
references	Bregnard *et al.*, 1996 Hunkeler, 1997 Hunkeler *et al.*, 1995	Bolliger *et al.*, 1998

5. COSTS

Not available.

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Project No. 8			
Obstruction of Expansion of a Heavy Metal/Radionuclide Plume Around a Contaminated Site by Means of Natural Barriers Composed of Sorbent Layers			
Location Not applicable	**Project Status** Interim Report	**Media** Soil and groundwater	**Technology Type** *In situ* absorption and solidification/ stabilization
Technical Contact Resat Apak Istanbul University Avcilar Campus, Avcilar 34850 Istanbul Turkey tel: 90/212-591-1998 fax: 90/212-591-1997 e-mail: rapak@istanbul.edu.tr	**Project Dates** Accepted 1998 Final Report 2000	**Contaminants** Heavy metals (Pb, As, Cr, Cu, Cd, Hg, Ni, Zn) and radionuclides (^{137}Cs, ^{90}Sr, ^{238}U)	
	Costs Documented? No	**Project Size** Bench-scale	**Results Available?** No

1. INTRODUCTION

Development of unconventional sorbents for heavy metals/radionuclides; determination of sorption/desorption parameters and solidification/stabilization conditions; exhibition of *in situ* physical/chemical treatment technologies applicable to a spill site.

2. DESCRIPTION OF SITE

Not applicable

3. DESCRIPTION OF METHODS

Physical/chemical characterization of developed sorbents; batch and column tests for contaminant removal, collection of kinetic and equilibrium data, laboratory and field testing of solidification/stabilization process in terms of metal leachability and setting times of hardened blocks.

4. ANTICIPATED RESULTS AND EVALUATION

Results not available. Performance will be evaluated in terms of capacity and speed of sorbents, and of solidification/stabilization efficiency of the contaminants.

5. COSTS

Not available

6. REFERENCES AND BIBLIOGRAPHY

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R. Apak, G. Atun, K. Güçlü and E. Tütem, "Sorptive removal of cesium-137 and strontium-90 from water by unconventional sorbents. II. Usage of coal fly ash," *J. Nucl. Sci. Technol*., 33 (1996) 396-402.

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R. Apak, E. Tütem, M. Hügül and J. Hýzal, "Heavy metal cation adsorption onto unconventional sorbents (red muds and fly ashes)," *Water Research* (1997) in press.

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E. Tütem and R. Apak, "The role of metal-ligand complexation equilibria in the retention and mobilization of heavy metals in soil," Contaminated Soil "95 Proceeding of the Fifth International FZK/TNO Conference on Contaminated Soil, 30 Oct.-3 Nov. 1995, Maastricht, Netherlands, W. J. van den Brink, R. Bosman and F. Arendt (eds.), Kluwer Academic Publishers, Vol. I, 425-426.

R. Apak, "Sorption/solidification of selected heavy metals and radionuclides from water", NATO/CCMS Pilot Study International Meeting on "Evaluation of Emerging and Demonstrated Technologies for the Treatment of Contaminated Land and Groundwater," 17-21 March, 1997, Golden, Colorado, USA.

Project No. 9

Solidification/Stabilization of Hazardous Wastes

Location	Project Status	Media	Technology Type
Middle East Technical University, Ankara, Turkey	Initial Project Description	Soil and Solid Wastes from mining and paper and pulp industries	Solidification/ Stabilization
Technical Contact	**Project Dates**	**Contaminants**	
Kahraman Ünlü Middle East Technical University Environmental Engineering Dept. 06531 Ankara Turkey tel: 90-312-210-5869 fax: 90-312-210-1260 E-mail: kunlu@rorqual.cc.metu.edu.tr	Accepted 1998 Final Report 2000	PCBs, AOX, heavy metals	
	Costs Documented?	**Project Size**	**Results Available?**
	No	Bench-scale	No

1. INTRODUCTION

With the enforcement of the regulation of the *Control of Hazardous Wastes* (C of HW) in August 1995, the direct or indirect release of hazardous wastes into the receiving environment in such a manner that can be harmful to human health and the environment is banned in Turkey. The main purpose of the regulation is to provide a legal and technical framework for the management of hazardous wastes throughout the nation. In this regard, the regulation is applicable not only to hazardous wastes generated in the future, but also with existing hazardous wastes and their safe disposal in compliance with the current regulation.

Solidification/stabilization (S/S) technology is recognized by the Turkish regulation of the C of HW as a promising new emerging technology for the safe disposal of hazardous wastes. Thus, this project focuses on investigating the effectiveness of S/S technology by conducting bench-scale treatability tests with contaminated soils and various types of hazardous waste materials. The major objectives of the project are to: (i) investigate the effectiveness and reliability of the S/S technology for the safe disposal of hazardous wastes containing metal and organic contaminants; (ii) determine the appropriate technical criteria for applications based on the type and composition of hazardous wastes; and (iii) determine the unit costs associated with the field-scale applications of the S/S technology.

2. SITE DESCRIPTION

(not applicable)

3. DESCRIPTION OF THE PROCESS

The following technical criteria will be considered for the evaluation of the effectiveness of the S/S technology for the safe disposal of hazardous wastes containing metal and organic contaminants: (i) determining the mobility of contaminants in the waste via conducting leaching and permeability tests on solidified/stabilized samples; and (ii) determining the strength of solidified samples against deformation and deterioration by conducting comprehensive strength tests on, and measuring microstructural characteristics of, solidified samples. In this study, metals will be tested on a waste from gold mining, organics on PCB-contaminated soil, and sludge and/or wastewater from paper and pulp industry for adsorbable organic halides (AOX). If necessary, synthetic waste materials representing the composition of “typical wastes” containing metal and organic contaminants will also be prepared.

For solidification of waste and encapsulation of contaminants, portland cement as a binding agent will be mixed with waste materials at different ratios. This ratio will be determined based on the particle size distribution of waste materials. In general, as the fraction of fine particles in the waste increases, the amount of portland cement to be used decreases. On the other hand, as the fraction of coarse particles in the waste increases, the strength of solidified waste against deformation increases at the same ratio of portland cement and waste material mixture. Waste material and portland cement mixing ratios will be determined considering these general facts.

In this project, for each of the mining waste and PCB-contaminated soil materials, three samples, representing fine, medium and coarse particle size distributions, will be prepared (for a total of six samples). For each waste material representing a given particle size distribution class, two different portland cement mixing ratios will be used: for metal contaminants (mining waste) 5 and 15%; for PCB-contaminated soil 20% and 35%; and for AOX-containing sludge or wastewater 1:6 and 1:8 waste:portland cement. A total of 14 waste samples prepared in this manner will be cured nearly 28 days to solidify. The following physical tests and measurements will be performed on these solidified samples: comprehensive strength and microstructural tomography, permeability, porosity, and bulk density. In addition to these tests and measurements, standard TCLP tests of the U.S. EPA will be performed on the same solidified waste samples. The same leaching tests will also be performed on unsolidified samples. On the leachate, concentrations of the following contaminants will be measured: As, Cd, Cr, Cu, Fe, Ni, Pb, Zn, Ca, Mg, Na, K, Cl, SO_4, HCO_3, pH, PCB and AOX. Based on the results of the physical tests and comparisons of the leachate compositions obtained from solidified and unsolidified waste samples, for each waste type, the effectiveness of the S/S technology in terms of contaminant encapsulation will be accomplished. For all chemical analyses, U. S. EPA SW-846 standard methods will be used.

4. RESULTS AND EVALUATION

Not available

5. COSTS

Not available

<table>
<tr><td colspan="4">Project No. 10

Metal-Biofilm Interactions in Sulfate-Reducing Bacterial Systems</td></tr>
<tr><td>Location
Under development in consortium’s laboratories</td><td>Project Status
Accepted 1998</td><td>Media
Liquid effluents in Groundwater</td><td>Technology Type
Biological treatment</td></tr>
<tr><td rowspan="2">Technical Contact
Dr. Harry Eccles
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BNFL
Springfields, Preston PR4 0XJ
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tel: +44/1772-762566
fax: +44/1772-762891</td><td>Project Dates
1996-1999</td><td colspan="2">Contaminants
Toxic heavy metals (Cu, Zn, Cd) and radionuclides (U)</td></tr>
<tr><td>Costs Documented?
No</td><td>Project Size
Laboratory-scale</td><td>Results Available?
No</td></tr>
</table>

1. INTRODUCTION

The development of sulfate-reducing bacteria (SRB) to remove toxic heavy metals and radionuclides from liquid effluents or contaminated groundwater is currently at laboratory scales to provide fundamental data to enable engineers to better design the bioreactors.

SRB technology for removal of toxic heavy metals has ben used on a limited number of occasions. In general, the bioreactors have been over-engineered, thus increasing both the capital and operational costs. Consequently, the technology the technology is not perceived as competitive. With intrinsic bioremediation, under anaerobic conditions such as wetlands technology, SRB plays a role in the sequestration of metals. It is not fully understood if this SRB role is complementary or pivotal. If the latter function predominates then understanding SRB-metal precipitation mechanisms could enable the wetlands to be better engineered/ controlled leading to more effective *in situ* treatment.

The goal of this project is to generate new metal-biofilm fundamental data by:

- further developing the laboratory biocell to produce precise data.
- investigating factors affecting growth of sulfate-reducing bacterial (SRB) biofilms.
- examination of the influence of this SRB biofilm on metal immobilization.
- quantification of important biofilm parameters on metal immobilization.

2. SITE DESCRIPTION

The studies are being carried out in the consortium’s laboratories

3. DESCRIPTION OF THE PROCESS

Biological processes for the removal of toxic heavy metals are presently less favored than their chemical and physicochemical counterparts. Reasons for this are several, one of which is the inability to intensify the technology due to the lack of fundamental data. BNFL and its partners intend, using a novel biofilm reactor design to provide such information which can be used by the consortium’s biochemical engineers and biofilm modelers to design better, smaller and more efficient bioreactors incorporating SRB technology.

These bacteria are capable of reducing sulfate ions in liquid waste streams to hydrogen sulfide, which with many toxic heavy metals, will precipitate them from solution as their insoluble sulfides.

As the solubility products of these sulfides are very small (at least 10^{-10} less than the corresponding metal hydroxide) the final treated effluent will meet the most stringent specification. Just as the biological system is an active metabolic one, the initial metal concentrations can be comparatively high—a few hundred parts per million.

The project commenced on 1 April 1996 and should terminate on the 31 March 1999.

4. RESULTS AND EVALUATION

Key components of this project are to consistently grow uniform well characterized SRB biofilms at two independent research institutions and to generate kinetic and thermodynamic metal adsorption and precipitation data. These quality criteria have required:

- verified analytical and experimental protocols to be developed.
- the design and construction of a biocell which satisfies some of the above criteria.
- biofilm characterization procedures.
- the identification of initially, simple models for both biofilm and bioreactor which can be modified to accommodate experimental data.

All of the above have been fully achieved or are ongoing.

5. COSTS

Not applicable at this stage.

6. REFERENCES AND BIBLIOGRAPHY

There are numerous SRB publications but little is relevant to this particular project. One scientific paper is currently awaiting publication whist the consortium members are at present writing a specific textbook addressing SRB-metal removal and modeling of bioreactors and biofilms.

Project No. 11

Predicting the Potential for Natural Attenuation of Organic Contaminants in Groundwater

Location	Project Status	Media	Technology Type
Operational coal tar processing and organic chemicals manufacturing plant, West Midlands, U.K.	First progress report	Groundwater	Intrinsic bioremediation, natural attenuation

Technical Contact	Project Dates	Contaminants	
Dr Steve Thornton, Groundwater Protection & Restoration Group, Dept. of Civil & Structural Engineering, University of Sheffield, Mappin St. SHEFFIELD S1 3JD, United Kingdom, tel: 0114 222 5744, fax: 0114 222 5700, E-mail: s.f.thornton@sheffield.ac.uk	Accepted 1998 Final Report 1999	Coal tars, phenol, creosols, xylenols, BTEX	
	Costs Documented?	**Project Size**	**Results Available?**
	Not applicable	Not applicable	Yes

Active restoration of contaminated aquifers is technically difficult and costly. A cheaper and potentially more effective alternative is to use natural attenuation (intrinsic bioremediation). This is an emerging technology, which uses natural biological and chemical processes occurring in aquifers to reduce contaminants to acceptable levels. The technology has been used successfully in shallow North American aquifers but has not been developed for the deep, fractured, consolidated aquifer systems found in the U.K. The project objectives are (a), to understand processes controlling the natural attenuation of a complex mixture of organic pollutants in a U.K. sandstone aquifer, (b), to develop practical techniques to estimate the potential for natural attenuation and (c), to understand the value of intervening to increase attenuation. The key issues under research are (a), estimating the timing and duration of degradation, (b), understanding the degradation processes and potential inhibitors, (c), quantifying the role of mineral oxidants in degradation, (d), assessing the supply of soluble electron acceptors from dispersion and diffusion at the plume fringe, and (e), assessing the contribution of fermentation to degradation.

The research site is an operational coal-tar processing and phenols manufacturing plant in the U.K. West Midlands. The plant lies on a deep, unconfined, fractured sandstone aquifer and has contaminated the groundwater with a range of phenolic compounds, including phenol, cresols, xylenols and BTEX, some at concentrations up to 12,000mg/L. Groundwater levels are shallow (<5 meters below ground level) and the horizontal groundwater velocity is 4-11m/yr. The regional groundwater flow is controlled by abstraction from a public supply borehole, 2km from the site. A large contaminant plume ($3Mm^3$ volume) has developed as a result, which has dived 60m over 500m from the plant. The aquifer is naturally aerobic, calcareous at depth and contains abundant Fe and Mn oxides as grain coatings.

The project began in September 1996, in collaboration with the British Geological Survey and Institute of Freshwater Ecology, and is 3 years duration. Simultaneous field investigations, laboratory studies and reactive transport modeling is underway. The range of redox and microbial processes identified in the plume has demonstrated the aquifer potential for aerobic and anaerobic degradation of the organic contaminants. Degradation rates and microbial activity are highly variable and are correlated with contaminant concentrations, nutrient supply and electron acceptor availability in the plume. A carbon and electron acceptor mass balance for the plume has constrained the plume source term and suggests that degradation has not been significant (Thornton, *et al*., submitted). High-resolution multilevel samplers (MLS) have been installed in the plume to quantify solute fluxes, degradation rates and identify redox processes.

Microcosm studies using acclimated groundwater and aquifer sediment are underway to examine the degradation rates of phenolic mixtures under the range of redox and environmental conditions found in the plume. Additional process studies are planned, using a core of contaminated aquifer material, which will examine the spatial variability in aquifer degradation potential, and also to quantify the bioavailability of mineral oxidants in degradation. Reactive transport modeling of biodegradation processes in the plume is in progress. The necessary parameter values, rate data and processes required for modeling are obtained from the laboratory and field studies. This will provide an independent assessment of the utility of the approach in predicting contaminant fate at field-scale.

REFERENCE

Thornton, S.F., Davison, R.M., Lerner, D.N. and Banwart, S.A. (submitted). Electron balances in field studies of intrinsic bioremediation. GQ98 International IAHS conference on *Groundwater Quality: Remediation and Protection*, 21-25th September, Tübingen, Germany.

<table>
<tr><td colspan="4">Project No. 12

Treatability Test for Enhanced In Situ Anaerobic Dechlorination</td></tr>
<tr><td>Location
Five DOD locations in the U.S.</td><td>Project Status
Five treatability tests to be conducted during 1998-1999</td><td>Media
Groundwater</td><td>Technology Type
In situ anaerobic biodegradation of chlorinated ethenes in groundwater</td></tr>
<tr><td rowspan="2">Technical Contact
Catherine Vogel
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gale_onorato@
ccmail.aleq.tyndall.af.mil</td><td>Project Dates
Accepted 1998</td><td colspan="2">Contaminants
Chlorinated solvents: PCE, DCE, TCE, VC</td></tr>
<tr><td>Costs Documented?
No</td><td>Project Size
Treatability Study</td><td>Results Available?
No</td></tr>
</table>

1. INTRODUCTION

- Name and type of technology: *In situ* anaerobic dechlorination for chlorinated ethenes in groundwater.
- Status of technology: Emerging/innovative.
- Project objectives: To develop and validate a protocol for conducting a treatability test for enhanced anaerobic dechlorination. The protocol will be applied and evaluated at five Department of Defense (DOD) sites within the United States.

2. SITE DESCRIPTION

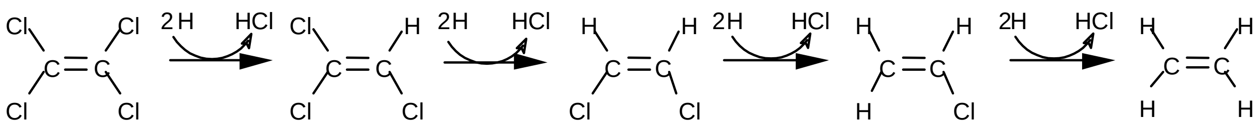
The first site is located at Cape Canaveral Air Station, FL. A shallow groundwater contamination plume containing primarily TCE, DCEs, and VC exists in a remote portion of the facility. Other DOD sites are currently being screened for inclusion in this project.

3. DESCRIPTION OF THE PROCESS

In situ enhanced anaerobic dechlorination involves stimulating native aquifer microorganisms to reduce chlorinated aliphatic contaminants. This is achieved by supplying excess electron donor to the contaminated aquifer. As the natural electron acceptors (sulfate, nitrate, iron, etc.) are depleted, microorganisms capable of utilizing the chlorinated contaminants as electron acceptors gain a selective advantage. The intricacies of these microbial communities are complex, but recent research has provided some insight into methods for enhancing populations of contaminant degrading microorganisms.

The reductive dechlorination of tetrachloroethene (PCE) to ethene proceeds through a series of hydrogenolysis reactions (see Figure 1). Each reaction becomes progressively more difficult to carry out;

subsequently, the dichloroethenes (DCEs) particularly *cis*-DCE, and vinyl chloride (VC) tend to accumulate in anaerobic environments.



PCE TCE DCEs VC ETH

Figure 1. Reductive Dechlorination of PCE

The selection of an appropriate electron donor may be the most important design parameter for developing a healthy population of dechlorinating microorganisms. Recent studies have indicated a prominent role for molecular hydrogen (H_2) in the reductive dechlorination of chloroethenes (Figure 2). Most known dechlorinators can use H_2 as an electron donor, and some can only use H_2. Because more complex electron donors are broken down into metabolites and residual pools of H_2 by other members of the microbial community, they may also be used to support dechlorination.

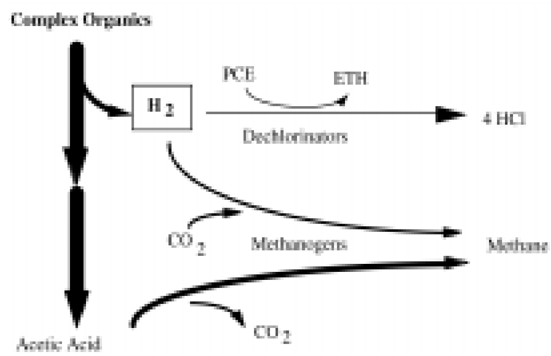


Figure 2: Role of Hydrogen in Reductive Dechlorination

The rate and quantity of H_2 made available to a degrading consortium must be carefully engineered to limit competition for hydrogen from other microbial groups, such as methanogens and sulfate-reducers. Competition for H_2 by methanogens is a common cause of dechlorination failure in laboratory studies. As the methanogen population increases, the portion of reducing equivalents used for dechlorination quickly drops and methane production increases. The use of slowly degrading non-methanogenic substrates helps to prevent this type of system shutdown and allow a larger zone of treatment in the subsurface.

This effort includes the development and multi-site validation of a protocol for conducting a treatability test for enhanced in-situ anaerobic dechlorination. During 1997, the protocol was developed and peer-reviewed twice. The document is now available to the general public through AFRL. Components of the protocol include; hydrogeologic and geochemical site characterization, microcosm studies, design/construction of the field treatability test, test monitoring, and data interpretation.

Through 1998-1999, the protocol will be applied at five DoD chlorinated solvent contamination sites. Microcosm studies are conducted to determine what electron donor/nutrient formulation will be field tested to provide optimum biological degradation performance. The design for the field-scale treatability study consists of three injection wells, two extraction wells and a series of nested monitoring wells located between the injection and extraction wells. The three closely spaced injection wells inject contaminated site groundwater that has been extracted from a down-gradient extraction well and amended with electron donor and nutrients. The simultaneous injection and extraction of site groundwater at opposite ends of the test plot imposes a hydraulic gradient that directs local groundwater flow. The systems will be operated and monitored for a minimum of six months at each site.

The final, validated protocol will be released in spring 2000.

4. RESULTS AND EVALUATION

Results not available at this time.

5. COSTS

Specific costs are not available at this time. However, this technology offers an in-situ, destructive approach to remediating chlorinated groundwater contamination plumes. It is estimated that the Air Force alone has 800 sites requiring some kind of remediation action. Natural Attenuation, the preferred approach, is estimated to only be applicable at 15-20% of these sites. The remainder will most likely require some type of active cleanup. This in-situ cleanup approach will help to fill this technology gap.

Project No. 13			
Permeable Reactive Barriers for *In Situ* Treatment of Chlorinated Solvents			
Location Dover AFB, DE	**Project Status** Field Work On-going	**Media** Groundwater	**Technology Type** *In situ* abiotic destruction of contaminants
Technical Contact 1Lt Dennis O'Sullivan AFRL/MLQE Tyndall AFB, FL 32403-5323 Tel: 850-283-6239 Fax: 850-283-6064 E-mail: dennis_o'sullivan@ ccmail.aleq.tyndall.af.mil Randy Wolf (BDM) Same address as above Tel: 850-283-6187 Fax: 850-283-6064 E-mail: randy_wolf@ ccmail.aleq.tyndall.af.mil	**Project Dates** Accepted 1998	**Contaminants** Chlorinated solvents: PCE, DCE, TCE	
	Costs Documented? Yes	**Project Size** Pilot-scale	**Results Available?** No

1. INTRODUCTION

The use of the funnel-and-gate approach to treat groundwater is being commercialized. However, researchers are currently working on improved reactive materials to place in the gate portion of the wall. The objectives of the project are to determine the effectiveness of alternative reactive media for the funnel-and-gate system at the field-scale level. Generate engineering and cost data which will be included in a validated design guidance manual (to be published in late 1999).

2. SITE DESCRIPTION

Area 5 at Dover Air Force Base (AFB), Delaware, was selected for the permeable barrier demonstration because it has a suitable aquifer containing perchloroethylene (PCE), trichloroethylene (TCE), and dichloroethylene (DCE). It has a reasonably deep aquifer, competent aquitard (confining layer), and significant concentrations of chlorinated solvents (several parts per million). This site has several challenges that have not been studied in barrier installations to date. Shallow regions of the aquifer have high levels of dissolved oxygen (DO). High DO causes precipitation at the front end of the barrier that may result in plugging of the reactive media and development of preferential flow paths over time. DCE, which exists in relatively high concentrations, is somewhat more resistant to reduction than PCE and TCE. Significant variability in the seasonal groundwater flow direction could affect the hydraulic capture of the plume. Finally, underground utilities complicated the barrier installation.

3. DESCRIPTION OF THE PROCESS

The main objective of this technology demonstration is the testing of alternative reactive media at a field-scale, proof-of-principle demonstration for in situ permeable reactive barriers. A funnel-and-gate system consisting of two separate 8-foot wide gates was installed in December 1997. This demonstration includes the testing of two reactive media schemes and also involved innovative emplacement methods to reduce the construction costs of permeable barrier systems. The 45-foot deep barriers were constructed with 8-foot diameter caissons that were removed after media emplacement. The funnel sections were constructed using Waterloo interlocking sheet piling driven to the 45-foot depth and keyed into the underlying clay aquitard. One gate was filled with zero-valent iron filings with a 10 percent iron/sand pretreatment zone to stabilize flow and remove dissolved oxygen. The second gate was also filled with zero-valent iron but is preceded by a 10 percent pyrite/sand mixture to moderate the pH of the reactive bed, thereby decreasing precipitate formation.

Monitoring wells were placed in the aquifer (both up gradient and down gradient from the reactive barrier) and within both of the treatment gates. Monitoring of these wells during a period of one year after the barrier installation will study the following parameters:

- contaminant and byproduct concentrations along the flow paths
- reaction rates of dechlorination processes
- dissolved oxygen consumption in the pretreatment zone of each gate
- water levels within the gates to evaluate residence times
- upgradient water levels to evaluate flow divides and capture zones
- downgradient water levels to gain knowledge of remixing and flow conditions downstream from the barrier
- homogeneous or preferential flow
- inorganic water quality parameters

A permeable barrier design guidance document was concurrently developed and reviewed by state and federal regulators. The design guidance addresses treatability testing, design, installation, and monitoring of barrier technologies in variable geological settings. The design guidance includes input from the Air Force, Army, Navy, numerous industry partners, state and federal regulators and the Remediation Technologies Development Forum Permeable Barriers Action Team. Data from the Dover AFB demonstration will be used to “validate” the design guidance manual.

At least two rounds of performance data will be available for presentation at the Spring 1999 NATO/CCMS meeting. The validated design guidance manual will be available for distribution to the NATO/CCMS group at the Year 2000 meeting.

4. RESULTS AND EVALUATION

Results not available at this time.

5. COSTS

Permeable reactive barriers may reduce operations and maintenance costs by at least 50 percent over pump-and-treat systems throughout the life of the treatment. The use of this technology could result in total US Air Force savings of $25 million. The technology enhancements gained from this field demonstration will result in even greater savings through the use of alternative media and the ability to emplace the media to greater depths.

Project No. 14 **Dynamic Underground Stripping**			
Location Southern California Edison Co. Pole Treating Site, Visalia, CA	**Project Status** New	**Media** Groundwater and soil	**Technology Type** Hydrous Pyrolysis/Oxidation
Technical Contact Paul M. Beam U.S. Department of Energy 19901 Germantown Road Germantown, MD 20874-1290 United States tel: 301-903-8133 fax: 301-903-3877 e-mail: paul.beam@em.doe.gov	**Project Dates** Accepted 1998	**Contaminants** PAHs and pentachlorophenol	
	Costs Documented? Yes	**Project Size** Full-Scale; 4.3 acres	**Results Available?** Yes (Preliminary)

1. INTRODUCTION

In the early 1990s, in collaboration with the School of Engineering at the University of California, Berkeley, Lawrence Livermore developed dynamic underground stripping, a method for treating subsurface contaminants with heat that is much faster and more effective than traditional treatment methods. More recently, Livermore scientists developed hydrous pyrolysis/oxidation, which introduces both heat and oxygen to the subsurface to convert contaminants in the ground to such benign products as carbon dioxide, chloride ion, and water. This process has effectively destroyed all contaminants it encountered in laboratory tests.

2. SITE DESCRIPTION

During the summer of 1997, both processes were used for cleanup of a four-acre site in Visalia, California, owned by Southern California Edison. The utility company had used the site for 80 years to treat utility poles by dipping them into creosote, a pentachlorophenol compound, or both. By the 1970s, these highly toxic substances had seeped into the subsurface to depths of approximately 100 feet.

3. DESCRIPTION OF THE PROCESS

In the heating process in hydrous pyrolysis/oxidation, the dense, nonaqueous-phase liquids and dissolved contaminants are destroyed in place without surface treatment, thereby improving the rate and efficiency of remediation by rendering the hazardous materials benign by a completely *in situ* process. Hydrous pyrolysis/oxidation also takes advantage of the large increase in mobility that occurs when the subsurface is heated, which makes contaminants more available for destruction. Many remediation processes are limited by the access of the reactants to the contaminant, making mobility the bane of remediation efforts in low-permeability materials such as clays.

Most early Livermore experiments on the hydrous pyrolysis/oxidation process, funded by the Department of Energy, were with trichloroethylene (TCE), a solvent that used to be widely used in degreasing and other industrial processes. TCE is the most common solvent ground water contaminant in the Department of Energy complex. Unlike gasoline, TCE and similar solvents are heavier than water, which mans that they can sink below the water table, making cleanup extremely difficult if not impossible with conventional methods.

The oxidation process occurs naturally, but without heat it is very slow. So the Livermore team needed to know how hot the soil needed to be. They learned that with TCE, just a few degrees can make an enormous difference in how quickly the breakdown occurs. At 90ºC, it takes a few weeks, at 100ºC, a few days, and at 120ºC, it occurs in just a few hours. Laboratory results indicated that the contaminants at Visalia would react at similar rates to TCE.

4. RESULTS AND EVALUATION

Southern California Edison and Steam Tech of Bakersfield, California, the first commercial site licensee of the dynamic underground stripping technology, are cleaning up the Visalia site, with Livermore staff periodically on hand as operational consultants. During the first six weeks of operation, between June and August 1997, the team removed or destroyed in place approximately 300,000 pounds of contaminant, a rate of about 46,000 pounds per week. For nearly 20 years, Southern California Edison had been removing contaminant from the subsurface using the standard cleanup method, known as pump-and-treat, most recently at a rate of just 10 pounds per week. In fact, the amount of hydrocarbons removed or destroyed in place in those six weeks was equivalent to 600 years of pump-and-treat. Needless to say, the Visalia cleanup using dynamic underground stripping and the first field use of hydrous pyrolysis/oxidation is considered a wild success by everyone involved.

The demonstration of hydrous pyrolysis/oxidation at Visalia confirmed the effectiveness of this technology for dense heavier-than-water ground water pollutants. So resistant to cleanup in the past, these contaminants include such widely used compounds as carbon tetrachloride, a chemical used as a refrigerant and a dry-cleaning solvent, and polychlorinated biphenyls (PCBs), a chemical used in electrical transformers and capacitors. The method can be used to clean up ground water and soils to almost any depth.

Work at Visalia is not yet complete. The boilers are no longer running, but the heated soil continues to vaporize contaminants at a high rate. The amount of total contamination is not known, so it is yet unclear how long Southern California Edison will have to continue monitoring. The best estimates today are that cleanup will be complete in a year, with another four years of monitoring the site.

5. COSTS

The first application of dynamic underground stripping cost about $110 per cubic yard, although Livermore scientists felt that they could repeat the project for about $65 per cubic yard. Because contamination at the gasoline spill was deep, digging up the contaminated soil and disposing of it would have cost almost $300 per cubic yard. (Soil removal and disposal costs are more typically in the $100 to $200 range.) The pump-and-treat method costs are as high or higher than soil removal.

With dynamic underground stripping, the contaminants are vaporized and vacuumed out of the ground, leaving them still to be destroyed elsewhere. In fact, about half the cost of a typical cleanup is in treating the recovered ground water and hauling away and disposing of the contaminated material that is brought to the surface.

Livermore's hydrous pyrolysis/oxidation technology takes the cleanup process one step further by eliminating the treatment, handling, and disposal requirements and destroying the contamination in the ground. The Visalia pole yard cleanup is the only application of this method to date, but indications are that large-scale cleanups with hydrous pyrolysis/oxidation may cost less than $25 per cubic yard., an enormous savings over current methods. Best of all, the end product of a hydrous pyrolysis/oxidation cleanup with bioremediation as a final step is expected to be a truly clean site.

6. REFERENCES AND BIBLIOGRAPHY

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Knauss, KG Aines, RD., Dibley, M. J. Leif, RN, and Mew, DA (1997) Hydrous Pyrolysis/Oxidation: In-Ground Thermal Destruction of Organic Contaminants. Lawrence Livermore Laboratory, UCRL-JC-126636.

<table>
<tr><td colspan="4">Project No. 15
Phytoremediation of Chlorinated Solvents</td></tr>
<tr><td>Location
Aberdeen Proving Grounds
Edgewood Area J-Field Site,
Edgewood, MD

Edward Sears Site,
New Gretna, NJ

Carswell Air Force Base,
Fort Worth, TX</td><td>Project Status
Interim Report</td><td>Media
Groundwater</td><td>Technology Type
Phytoremediation</td></tr>
<tr><td rowspan="2">Technical Contact
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Accepted 1998</td><td colspan="2">Contaminants

Chlorinated solvents: TCE, PCE, DCE, TMB, xylene, methyl chloride</td></tr>
<tr><td>Costs Documented?
Yes (preliminary)</td><td>Project Size
Full-Scale Field Demonstration</td><td>Results Available?
Yes (preliminary)</td></tr>
</table>

1. INTRODUCTION

The efficacy and cost of phytoremediation with respect to the cleanup of shallow groundwater contaminated with chlorinated solvents, primarily trichloroethylene (TCE), is being evaluated at the field scale in demonstration projects at Aberdeen Proving Grounds Edgewood Area J-Field Site in Edgewood, Maryland, the Edward Sears site in New Gretna, New Jersey, and Carswell Air Force Base in Fort Worth, Texas. These projects will demonstrate the use of hybrid poplars to hydraulically control the sites and ultimately to remove the contaminants from the groundwater. The objective of this study will be to evaluate and compare the results for these three sites with respect to the efficacy of phytoremediation under varied site conditions and in different climatic regions.

2. SITE DESCRIPTION

Aberdeen Proving Grounds, Maryland
The site is located at the tip of the Gunpowder Neck Peninsula which extends into the Chesapeake Bay. The Army practiced open trench (Toxic Pits) burning/detonation of munitions containing chemical agents, dunnage from the 1940s to the 1970s. Large quantities of decontaminating agents containing solvents were used during the operation. The surficial groundwater table had been contaminated with solvents (1122-TCA, TCE, DCE) at levels up to 260 parts per million (ppm). The contamination is 5-40 ft below ground surface. The plume is slow moving due to soils tight, silty sand. The impacted area is a floating mat-type fresh water marsh approximately 500 ft southeast. A low environmental threat is presented by the contaminant plume.

Edward Sears Site, New Jersey
From the mid-1960s to the early 1990s, Edward Sears repackaged and sold expired paints, adhesives, paint thinners, and various military surplus materials out of his backyard in New Gretna, NJ. As a result, toxic materials were stored in leaky drums and containers on his property for many years. The soil and groundwater were contaminated with numerous hazardous wastes, including methylene chloride, tetrachloroethylene (PCE), TCE, trimethylbenzene (TMB), and xylene. There is a highly permeable sand layer about 4-5 ft below ground surface (bgs), but below that exists a much less permeable layer of sand, silt, and clay from 5-18 ft bgs. This silt, sand, and clay layer acts as a semiconfining unit for water and contaminants percolating down toward an unconfined aquifer from 18-80 ft bgs. This unconfined aquifer is composed primarily of sand and is highly permeable. The top of the aquifer is about 9 ft bgs, which lies in the less permeable sand, silt, and clay layer. The top of the aquifer is relatively shallow and most of the contamination is confined from 5-18 feet bgs.

TCE concentrations in the groundwater ranged from 0-390 ppb. Most of the TCE is concentrated in a small area on site.

Carswell AFB, Texas
The U.S. Air Force Plant 4 (AFP4) and adjacent Naval Air Station, Fort Worth, Texas, has sustained contamination in an alluvial aquifer through the use of chlorinated solvents in the manufacture and assembly of military aircraft. Dissolution and transport of TCE and its degradation products have occurred, creating a plume of contaminated groundwater. This project is led by the U.S. Air Force (USAF) and is being conducted as part of the Department of Defense's (DOD's) Environmental Security Technology Certification Program (ESTCP), as well as the U.S. Environmental Protection Agency's (US EPA's) Superfund Innovative Technology Evaluation (SITE) Program. Planting and cultivation of Eastern Cottonwood (*Populus deltoides*) trees above a dissolved TCE plume in a shallow (<12 ft) aerobic aquifer took place in spring 1996. Data are being collected to determine the ability of the trees, planted as a short-rotation woody crop, to perform as a natural pump-and-treat system.

3. DESCRIPTION OF THE PROCESS

Aberdeen Proving Grounds, Maryland
- After agronomic assessment, one acre plantation of two year old Hybrid Poplar 510, were planted 5-6 ft deep. Surficial drainage system installed to remove precipitation quickly, allow trees to use groundwater.
- 1122-TCA and TCE are 90% of the contaminants (total approx. 260 ppm solvents). USGS estimated 7000 gals/day removal would achieve hydraulic containment.
- Planted in the spring of 1996, trees have grown substantially. Duration of evaluation will be five years.
- Currently monitoring aquifer, contaminants and drawdown, transpiration gas, soil emissions, soil community and structure, sap flow, weather, and plantation emissions.

Edward Sears Site, New Jersey

- 118 hybrid poplar saplings (*Populus charkowiiensis x incrassata*, NE 308) were planted in a plot approximately one-third of an acre in size. The trees were planted 10 ft apart on the axis running from north to south and 12.5 ft apart on the east-west axis. The trees were planted using a process called deep rooting: 12-ft trees were buried nine feet under the ground so that only about 2-3 ft remained on the surface.
- Extra poplars that were left after the deep rooting was completed were planted to a depth of 3 ft, or shallow rooted. These extra trees were planted along the boundary of the site to the north, west, and east sides of the site. These trees will prevent rainwater infiltration from off-site.
- Planted in the December 1996, trees have grown substantially.
- Monitoring of the site includes periodic sampling of groundwater, soils, soil gas, plant tissue, and evapotranspiration gas. Continued growth measurements will also be made as the trees mature. Site maintenance also involves the prevention of deer and insect damage.

Carswell AFB, Texas

- The USAF planted 660 eastern cottonwoods in a one acre area. The species *P. deltoides* was chosen over a hybridized species of poplar because it is indigenous to the region and has therefore proven its ability to withstand the Texas climate, local pathogens, and other localized variables that may affect tree growth and health.
- Two sizes of trees were planted: whips and 5-gallon buckets. The 5-gallon bucket trees are expected to have higher evapotranspiration rates due to their larger leaf mass.
- Planted in the April 1996, trees have grown substantially (5-gallon buckets have grown faster than whips).
- Site managers plan to increase monitoring at the site to include a whole suite of water, soil, air, and tree tissue sample analysis. Some of the more unique data they are collecting (in relation to the other case study sites) are analyses of microbial populations and assays of TCE degrading enzymes in the trees.

4. RESULTS AND EVALUATION

Aberdeen Proving Grounds, Maryland

- Currently using sap flow instrumentation, during growing season trees are pumping approximately 1,500-2,000 gals/day with demonstrated aquifer drawdown. There are measurable parent compounds in the transpiration gas of leaves. OP-FTIR demonstrated non-detectable off-site migration of emissions from transpiration gas. Limitations include depth of contamination, but not concentrations of up to 260 ppm solvents. Weather and growing season are the most influential factors.
- Lessons learned include better pre-planting assessment of soil community and to anticipate the contribution from natural attenuation. Unfortunately, no formal monitoring was established to assess the progress of technology.

Edward Sears Site, New Jersey

- Sampling of evapotranspiration gas was conducted by placing Teflar bags over entire trees. Data from these air samples suggest that the trees are evapotranspirng some VOCs.
- Future sampling designs will attempt to determine accurate background VOCs.
- Site managers plan to sacrifice one tree either after or during the next growing season to determine the extent of root growth.

Carswell AFB, Texas

- Seventeen months after planting, tree roots had reached the water table (10 feet bgs).
- Transpiration measurements indicate that the largest planted trees transpired approximately 3.75 gpd during summer 1997; a nearby 19-year-old, 70-ft cottonwood tree growing southeast of the area was determined to transpire approximately 350 gpd.

- Experiments indicate that cottonwoods and willows produce enzymes that can degrade PCE and TCE, and that tree enzymes will likely contribute to attenuation of TCE at the site.
- TCE concentrations in groundwater samples collected beneath the 19-year-old cottonwood tree during summer 1997 were about 80 percent less than concentrations in groundwater beneath the planted trees, and concentrations of a TCE degradation by-product (cis-1,2-dichloroethylene) were about 100 percent greater.
- Trees are not yet hydraulically controlling the plume. Results of a groundwater flow model (MODFLOW) and a transpiration model (PROSPER) will be combined to determine when hydraulic control of the plume might occur. A solute-transport model (MOC3D) is planned to help determine the relative importance of various attenuation processes in the aquifer to guide data collection at future sites.
- Extensive studies of the subsurface biomass, chemistry, geochemistry, tree enzymes/kinetics, and microbial ecology of the cottonwood populations and nearby mature trees have been initiated.

5. COSTS

Aberdeen Proving Grounds, Maryland

Before treatment — $5,000

  Capital — $80,000 for UXO clearance of soil during planting; $80/tree.

  Operation and maintenance — $30,000, due to no established monitoring techniques

After treatment — None (trees remain in place)

Edward Sears Site, New Jersey

None

Carswell AFB, Texas

Before Treatment

- *Preparatory Work*
  - Site Characterization — $12,000
  - Site Design — $10,000
- *Site Work*
  - Monitoring (research level) well installation — $90,000
  - Development of Plantations - 1 acre (includes landscaping costs) — $41,000
- Weather Station — $3,100
- Survey — $25,000
- *Purchase of Trees*
  - Whips ($0.20 each) — $100
  - Five-gallon buckets ($18 each) — $2,000

Treatment

- Installation of Irrigation System — $10,000
- Yearly O&M
- Landscaping — $2,000
- Groundwater, soil, vegetation, transpiration, climate, soil moisture, and water-level monitoring (research level) — $250,000

After Treatment — None

COUNTRY TOURS de TABLE

AUSTRIA

Austria has a new "Landfill Ordinance." This new law specifies parameters related to the quality of the waste to be deposited in landfills in terms of limit values for total pollutant content and related contaminant constituent values in waste samples. In addition, this law specifies four types of landfills: landfills for excavated soils, landfills for demolition waste, landfills for residual materials and solid or mass waste landfills, with each type of landfill legally accepting only certain types of waste. The following aspects of landfill operation are defined in the new landfill ordinance: waste acceptance inspections; waste generator identity checks; waste sample collection and analysis; special provisions for solidified wastes; precipitation run-off and management; and requirements for bottom-sealing systems (*i.e.*, landfill liner systems). This new law calls for the pre-disposal segregation of waste streams as well as improved pre-treatment of waste prior to disposal.

BELGIUM

1. Legal and Administrative issues

a. Background information

The Belgian institutional framework dividing the authority between the Federal State and the Regions confers the responsibility of environment protection policy almost exclusively to the Regions, with very few exceptions. And soil is no exception.

This means that there cannot be such thing as a federal legislation on Soil protection; the only common framework could come (as it is the case for Air, Water and Waste legislation) from the European Commission, where a proposal on civil liability for environmental damages is considered since 1993, but with limited chances of implementation in the near future.

Therefore, the three Regions, Flanders, Brussels Region and Wallonia, are free to act or not, in this issue, according to their own policy, the requirements of their citizens, and the constraints of their economy.

Until now, only Flanders has adopted a full legislative framework, although Brussels and Wallonia will probably present this year their own propositions.

b. Summary of Legislation

The Flemish Decree on soil remediation, adopted in 1995, has been brought into force in different stages through the end of 1996. The main characteristics cover five key issues:

- a register of contaminated land;
- the difference between historical and new soil contamination;
- the difference between duty and liability for decontamination;
- the soil decontamination compulsory procedure and control; and
- the transfer of land.

In addition, soil standards, background levels and intervention values have been adopted by the Flemish Government. The intervention values depend on future land use. Five groups of land uses have been distinguished. There is also a list of activities which could create soil pollution, and will need to be investigated (see §2).

c. The Concept of Contaminated Sites

One of the most significant features in the Flemish Decree is the difference created between “historical” and “new” pollution.

“Historical” soil pollution are those originated before the decree came into force; “new” soil pollution are those produced since the decree came into force. A “mixed” situation is also considered.

The clean-up of “new” pollution is, according to the decree, required as soon as the intervention values for soil clean-up are exceeded. For “historical” pollution on the contrary, the decision to clean-up will depend on the danger to man and the environment. So a site specific risk-assessment approach will be followed in this situation. Considering the limited financial resources available, the clean-up of historic pollution will follow a priority classification established by the Flemish government.

d. Administrative Aspects

For institutional reasons (see §1.a), there is no Federal Agency for the Environment:

- OVAM (Public Waste Agency of Flanders) is the responsible authority for soil control and remediation in the Flemish Region.

- In Wallonia, as long as no decree on soil remediation has been passed, responsibilities are shared between two administrative bodies: the Walloon Waste Office is the responsible authority for landfills and other sites polluted by waste, and the Town and Country Planning Administration is responsible for derelict land and brownfield sites.

- In Brussels, the authority is the Brussels Institute for Environmental Management.

e. Summary of Anticipated Policy Developments

A Soil Decree is in preparation in Wallonia, which should be presented this year to legislative adoption. Guidelines for investigations and assessment, and soil criteria, are also prepared. Soil criteria, a mapping strategy and a possible ordinance are considered in the Brussels Region. Our next report will present the situation at the end of 1998 in the two Regions.

2. Registration of contaminated sites

a. Flanders

According to the new legislation, a soil register has been created in Flanders. The Flemish authorities proceed with a systematic examination of potentially polluted areas mainly on three occasions:

- at the time of property transfer;
- at the closure of licensed installations; and
- whenever the license (authorization) has to be renewed.

Considering the varying delays for industrial license renewals, a special soil control obligation has been introduced in the general authorization procedure; so the ultimate deadline seems to be the year 2003 (with intermediate deadlines in 1999 and 2001): by that time, all industrial sites in use should have been checked, and re-authorized or compelled to consider clean-up measures (to be implemented before 2006).

The information on soil pollution is compiled in the soil register under the administration of OVAM (Public Waste Agency of Flanders). This register serves as a data base for policy decisions and also as an instrument to protect and inform all potential land purchasers.

A “soil certificate” is requested for all sorts of property transfers. This system has increased the number of voluntary investigations, and sometimes induces voluntary remediations, in order to avoid to be listed as contaminated in the register.

The Flemish legislation lays a special responsibility on registered soil decontamination experts. These are the responsible body for soil examination, under the supervision of OVAM which selects them according to expertise criteria, and control their work.

According to OVAM'S Remediation Service*, at the end of February 1998, there were 5,528 potentially contaminated sites in different parcels of land listed in the soil register. As of the same date, there were about 8,000 parcels of land mentioned as contaminated in the register.

Remediation programs are launched for about 70 sites. Registered soil decontamination experts have to develop and carry out those programs, according to the procedure and soil standards. They will also have to control the final result of the clean-up, under the supervision of OVAM.

b. Wallonia

A registration system has existed since 1978 for industrial derelict land and brownfield sites, based on a specific town and country planning legislation aiming at the redevelopment of those sites. In 1989, a special program, entrusted to the GEHAT at Brussels University, was launched by the Town and Country Planning Administration to assess the risk of contamination on all registered sites. It is based on preliminary assessments and includes a four level risk ladder. The resulting data base serves for policy decisions, to select priorities for detailed site investigations, and for remediations plans if proven necessary.

A more elaborate hazard ranking system has been developed recently for dumping sites by the SPAQUE (Walloon Public Society for the Quality of Environment) under the supervision of the Walloon Waste Office. The ranking is performed on the basis of a check-list considering source, vectors and risk groups.

An estimation of about 5,000 potentially contaminated sites is currently mentioned; of these, 2,200 industrial derelict sites are already registered and classified in the Town & Country Planning data base. Among the sites presenting a high risk factor, about 90 have been submitted to detailed investigations (as of February 1998); a dozen are now benefitting from remediation programs. For sites presenting a lower risk factor, detailed investigations are ordered only when a redevelopment strategy is planned, whether by a public or a private operator. In addition, the SPAQUE assessed 17 heavily polluted "priority sites," among former dumping and deposit sites. Four of them are in the remediation process.

c. Brussels Region

No registration system is known at this moment. A first investigations/mapping strategy is in preparation.

3. Remedial methods

Until recently, there have been no comprehensive statistics on remedial methods and technologies used for clean-up in Belgium. The following soil and groundwater remediation techniques are available and used*:

1. Excavation and transport of contaminated material to a deposit site and/or processing of the contaminated soil.

2. Hydrodynamic methods, by means of drains, water remediation, processing of slurry, etc.

3. Use of degassing systems.

4. Use of isolation techniques (horizontal and vertical isolation by means of cement, clay, bentonite, bitumen, etc.

5. Immobilization techniques by means of cement, lime, absorption methods for oil, etc.

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*Data collected with the help of Ecorem n.v.

6. Remediation technologies: microbiological remediation, *in situ* and *ex situ* (landfarming, biopiles, etc.), water and chemical extraction, flotation, thermal treatment, steam-stripping, a combination of physico-chemical and biological remediation techniques, electro-reclamation, infiltration and wash out.

4. Research, Development, and Demonstration

For soils contaminated with heavy metals and metalloids, the following remedial techniques are in research and/or anticipated for use in the coming years:

- *In situ* immobilization by means of soil additives.
- Bio-extraction of heavy metals by means of micro-organisms in a slurry-reactor.
- Phyto-extraction by means of plants with increased capacities of metal-accumulation.

More generally, there is a great need and expectation for low-energy, cost-effective remedial technologies. Research is progressing in the Universities and Public research Institutes, mainly in microbiology and phytoremediation areas, although no comprehensive evaluation is yet available.

In Flanders, a risk-evaluation model was evaluated and approved by OVAM. Research has been implemented on the prioritization of historical soil pollution, and a decision-supporting system has been developed to estimate which technologies are most appropriate at this moment, taking the costs into account. OVAM is also chairing a Committee on “Normalization of soil remediation.”

5. Conclusions

Since the adoption of the Flemish Decree on soil remediation, there has been a growing recognition of soil and groundwater contamination issues in Belgium. The implementation and the first results of the Flemish Decree are generally considered satisfactory by Public authorities, and this stimulates the two other Regions, Brussels and Wallonia, to define their own policy. But these policies might be based on rather different legal schemes, clean-up guidelines and soil criteria. For instance, should these criteria be compulsory or subject to site-specific interpretation is a matter of debate in the two Regions.

At the same time, in the private sector, the big companies are preparing the ground, or even anticipating the future legal impositions. Their main question is now: to what extent will it be possible to adopt different strategies and levels of soil protection in the three belgian Regions? More generally, the two main problems to be tackled in the near future will probably be:

- the lack of resources of many liable parties, for the cleanup of historical pollution; and

- the cost-efficiency and environmental merit of the remediation programs, whether funded by public or private money.

CANADA

The past year has been one of very great change within the Canadian Government in the area of site remediation. The Departments of National Defence (DND) and Fisheries and Oceans (DFO) have been active in assessment and remediation of their contaminated sites. Environment Canada has carried out a number of site assessments at its properties. These will be followed by further assessments in the coming year and, potentially, some initial site remediation. Treasury Board, a central government agency, has given all departments until 31 March, 1999, to come up with an approximation of the financial liability which they may be facing as a result of contaminated sites.

While this has been occurring, there has been a decrease in the level of focus which Environment Canada has been putting into site remediation. Hazardous Waste Management Branch has been disbanded with its remaining functions being spread throughout other branches. The Waste Water Technology Institute has been purchased by Connor Pacific, a private company. The other Environment Canada group active in the field, the Emergencies Engineering Division, is being taken over by Science Applications International Corporation (Canada) [SAIC (Canada)]. This means that the bulk of expertise formerly resident within Environment Canada will now reside within groups who act as contractors to the department.

CZECH REPUBLIC

1. Legal and Administrative Issues

The Czech Constitution was established on 16 December 1992. The Act on the Environment No. 17/1992 was adopted from Federal law, as many other legal provisions. A new Environmental Policy was adopted in August 1995. A lot of existing laws dated prior to the division of Czechoslovakia has been gradually updated or replaced.

Legal protection of water was anchored in Water Act (No. 138) in 1973. Systematic approach for polluted soil remediation started in connection with the ecological damages assessment of former Soviet military bases in former Czechoslovakia in 1990. The second, more significant wave of soil pollution assessment is in progress now, in the connection with property transfers in privatization processes. The Federal Waste Act 238/1991 was replaced by the Act 125/1997.

There are three sources of financing for environmental projects in the Czech Republic: 1) the State Budget, 2) the State Environmental Fund (created mostly by pollution levies, *e.g.*, for emissions, for waste disposal), 3) the National Property Fund (created by money from privatization).

Legislation which is important for soil and groundwater pollution has been enacted in association with the privatization of former state property. Act No. 92/1991 on Conditions for the Transfer of State Property to Other Persons and connecting Methods of Assessing Environmental Liabilities of Companies for the Preparation of Privatization Projects (Methodological Instructions of the Ministry for Administration of National Property and Its Privatization of the Czech Republic and of the Ministry of Environment of the Czech Republic of May 18, 1992) introduced guideline limit levels for soil, soil gas, and groundwater. These limits have been implemented according to the future use of contaminated sites based on the environmental assessment of property to be privatized. Resolutions of the Government of the Czech Republic No. 455/1992 and No. 123/93 describe and limit the degree to which the State retains liabilities for past environmental damage (items of damage were contamination of groundwater, contamination of soil, and landfills of harmful wastes). Resolution of the Government of the Czech Republic No. 810/1997 changed the above mentioned Resolution when extending the environmental damages to be remediated in the sense of this document by contamination of constructions and their parts. Other legislation on soil quality presents Act No. 13/1994 concerning agricultural soil quality. Limits for discharging pumped out and treated water in the process of remediation are controlled by the Order No. 171/1992 on standards of admissible levels of water pollution. The Czech Army follows, of course, the above-mentioned laws and guidelines; there are additional special regulations issued by MoD such as the *Commander's Guide to Environmental Management* (1996).

There are three types of contaminated sites in the Czech republic:

- Former SA bases (Soviet occupation lasted from 1968 to 1991). Contaminated sites were evaluated by investigation carried out by environmental companies in 1990 and 1991. Contaminated sites were considered as those where concentration of pollutants more-or-less exceeded Dutch C limits or Czechoslovak Drinking Water Standards when contaminated groundwater was used for drinking water supply or due to historical use. If necessary, a new risk assessment may be carried out to distinguish which localities are (still) contaminated and/or are to be remediated.

- Czech army bases have no special or legal definition in the Czech Republic, nevertheless the initial assessment procedures differed in the past from the below mentioned

- Other sites are considered contaminated when concentration of pollutants in soils, rocks, groundwater, wastes, soil gas, and buildings are dangerous to the environment when deemed so by the Czech Environmental Inspectorate, mostly based on a risk assessment

The highest environmental authority is the Ministry of Environment. Each District Office has an environmental authority with responsibility for administrative tasks related to the environment. The Czech Environmental Inspectorate enforces the environmental laws through its 42 branches. There are separate divisions for water, air, wastes, forestry, and natural protection.

2. Registration of Contaminated Sites

Major problems include:

- The most widespread pollutants are oil products (petrol, diesel, kerosene, lubricating and heating oils), chlorinated aliphatic hydrocarbons (DCE, TCE, PCE) and heavy metals (As, Cr, Cu, Pb, Hg, Cd etc.), phenols, cyanides

- The most harmful and/or “untreatable” are organic refractants (PCBs, PAHs, wood-preserving agents, tars), radioactive materials, poisons and combat chemicals

- There are hundreds of illegal waste disposal sites, a lot of them without any legal or known owner or user.

- Registration of former waste disposal sites was slowed down by the lack of money at first. Only about 40 (50 percent) districts have gotten them registered.

- No common and complete registration of all former and recent contaminated sites exists.

Background information on site registration:

- Former SA bases have been completely registered, and their records of remedial progress are at the Ministry of Environment.

- Contaminated sites of the Czech Army are registered by Ministry of Defence and its regional branches (so called VUSS). A new concept of areal registration of contaminated and potentially contaminated sites with the help of GIS has been started.

- Registration of waste dumps and landfills with the help of questionnaires was started by one District Office in 1995.

- Registration of contaminated sites including waste dumps and landfills has been organized by MoE as a research project (10 districts are involved in the first phase). It is based on GIS.

The National Property Fund (NPF) has its own registration of those contaminated sites, for which remediation is financed of NPF, and which were privatized according Act No. 92/1991, or contaminated sites (with environmental assessment) where companies asked NPF for remediation financing during the the second phase of privatization (from 1992).

There were 60 contaminated former Soviet Army bases in the Czech Republic. Remediation will be accomplished at the most of them until 2000. The cleanup of the biggest ones—Mladá-Milovice and Ralsko-Hradèany—will last until 2006 and 2008, respectively. Registration of former SA bases is administered by MoE.

The eight biggest contaminated Czech military sites being returned to civilian use will be remediated until 2000-2005. The five other largest contaminated Czech military sites that will be used by the Czech Army also will be remediated until 2000-2005. Environmental assessment at both groups of sites was carried out according to the 1992 Methodical Instructions. Some 300 small contaminated military sites also exist that will be environmentally assessed, and some of them will be remediated step-by-step. The administration of contaminated sites is done by regional offices of MoD (VUSS); the central administration is carried out by MoD.

The National Property Fund of the Czech Republic administered and registered (and guaranteed remediation) 300 contaminated sites (particularly the second privatization phase) between 1991 and 1997. About 100 contaminated sites from the former privatization phase are neither registered nor guaranteed for remediation.

About 3,000 former illegal municipal or industrial waste dumps, without known ownership, exist throughout our country. A number of them contain harmful wastes and may pose a threat to the environment. Their registration will be carried out by District Offices, but only half of them have been done.

The estimated number of sites for future remediation are:

- Czech military sites: 300
- Contaminated sites guaranteed by the National Property Fund: 300-500
- Illegal waste dumps without known owner or user: 200

3. Remedial Methods

Summary data on remedial methods:

- Soils: *ex situ:* bioreclamation (petroleum hydrocarbons [HC], BTEX, PAHs), washing, leaching (heavy metals, PCBs); stabilization-solidification (HC, PAHs, PCBs); incineration (tars, HC, organic refractants (more or less experimental stage only); poisons; venting (chlorinated hydrocarbons [CHC]; HC, BTEX); and landfillin (heavy metals, organic refractants, HC).

- Soils: *in situ:* soil vapor extraction (HC, BTEX, CHC), bioreclamation plus washing (HC, PAHs, partially CHC), encapsulation (all pollutants).

- Groundwater: *pump and treat* (all pollutants).

- Groundwater: *in situ:* vacuum extraction (HC, BTEX, CHC); bioreclamation (HC, BTEX, PAHs); air sparging (HC, BTEX, CHC); cobalt radiation destruction (cyanides).

- Auxiliary *in situ* methods: air and hydraulic fracturing, well blasting, soil heating, surfactant flushing.

Factors influencing use of remedial methods include hydrogeological and physical properties of soil and rocks, chemico-physical properties of pollutants, target concentration of pollutants, amount of contaminated soils, infrastructure of contaminated site (buildings and roads which cannot be destroyed or removed), time and money.

Hydraulic methods when clean-up of oil pollution will be more supplemented with *in situ* bioreclamation in late phases of decontamination of aquifers. When both groundwater and soil are contaminated with chlorinated hydrocarbons, pump-and-treat will be combined from the very beginning with SVE, vacuum extraction, and/or air sparging. For very viscous hydrocarbons and organic refractants, or where time is vital, thermal or steam stripping should be introduced.

The cheapest, most effective, and reliable remediation of soil polluted with hydrocarbons is *ex situ* bioreclamation. When soils are contaminated simultaneously with volatile HC and CHC, the most effective method is soil vapor extraction (SVE). Pump-and-treat methods are reliable and versatile, but their cost-effectiveness decreases with time due to the decrease of pollutant concentrations. Incineration is too expensive, and until now was used only for very harmful substances such as poisons and some munitions chemicals, and some other nondegradable organics.

4. Research, Development, and Demonstration

The Ministry of Environment (MoE) provides research grants for topics of its choosing, such as environmental assessment, registration of former contaminated sites, and remediation methods. The grants are awarded following competitive bidding. MoD has funded aerial registration and inventories of military sites—including contaminated ones—with the help of Geographic Information Systems (GIS).

More detailed information on RD&D can be seen from the following (incomplete) list of research projects and demonstrations:

- Methodology of investigation and remediation of former waste dumps and waste disposal sites. The research report addressed description and evaluation of proper methods of investigation and remediation, and a proposal for classification and registration of waste dumps. The research was carried out in 1995 and cost 4.4 million Czech Crowns.

- Methodology of environmental assessment (1995-1996).

- Methodology of risk analysis, including new criteria of rock medium contamination (1995—cost 2 million Czech Crowns).

- Methods of quality assurance of investigation and remediation of former contaminated sites. There were evaluated by three separate methods: quality assurance of sampling methods, quality assurance of remedial methods, and quality assurance of geophysical investigation of soil and groundwater pollution (1997—cost 600,000 Czech Crowns).

- Areal registration of former contaminated sites “SESEZ,” including former waste disposal dumps. Registration has started in 10 districts with the help of GIS in 1996 and will last until at least 2000.

- National Property Fund helped to organism demonstrations of new remedial technologies, *e.g.*, the Environmental Technology Initiative Conference in Prague and at Kralupy and Vltavou, June 23-25, 1997.

- MoD organized “demonstration projects” financed by the Netherlands MoD dealing with a site assessment program for Czechoslovak military sites in 1992 and “Tackling Soil Pollution on Military Sites in Czechoslovakia” in 1992 and 1993.

MoE prepared among others the following grants for the next two years:

- Revitalization of the open cast brown coal mines in “Podkrušnohorská uhelná pánev” (in the Coal Basin below the Krušné hory Mountains).

- Restriction for the minimizing of large-scale surface and ground water pollution.

- Remedial technologies for pollution with chlorinated hydrocarbons.

- Risk assessment of former waste disposal sites which were used according Act No. 238/1991, or abandoned ones before the mentioned act's validity.

- Indicators of rock environment capacity for natural bioreclamation of significant pollutants.

5. Conclusions

Legislation is under development, because until now there were objections to the Waste Act. The main problems, more technical than financial, of contaminated sites are related to the environmental issues of privatization projects in the second phase of privatization. In particularly, there are some discrepancies between planned remedial goals on one hand and time and economical limits on the other. Both technical and legislative/financial difficulties are related to environmental assessments and the eventual remediation of orphan former waste dumps and the contaminated industrial sites from the first phase of privatization.

Remediation of fissured aquifers contaminated with chlorinated organics and refractants will pose a significant task for the future. One way to tackle it will be the research grants; another way may be the demonstration of up-to-date or developing technologies. Steam stripping and electroreclamation seem to be very promising; however, we have until now nearly no experience with them in our country.

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DENMARK

1. Legal and Administrative Issues.

Until today the main issues relating to contaminated land in Denmark are addressed in two laws, the Contaminated Sites Act (1983, revised in 1990 and 1996, called the Contaminated Sites Act) and the Environmental Protection Act of 1974, last amended in 1996. These two acts effectively supplement each other (with the exception of orphaned sites established after 1974).

Danish Environmental legislation is based on the Polluter Pays Principle (PPP). However, during recent years, several lawsuits have shown that strict liability for contaminated sites cannot be applied within Danish civil law. The Supreme Court has ruled against the Ministry of Environment and Energy in a number of cases, where it could not be proved that the polluter was acting *mala fide* at the time when the polluting activity was taking place.

A ruling from the Supreme Court in 1992 states that the normal time limit for liability in cases of soil contamination is 20 years. This means that in 1996 all claims concerning sites under the Contaminated Sites Act by definition are to old.

The Contaminated Sites Act

The Contaminated Sites Act allows the authorities to take and finance action at sites where contamination took place before legislation, like the Environmental Protection Act was implemented. Therefore, a contaminated site in Denmark is defined as:

- a site polluted with oil and oily waste before 1972, *or*
- a site polluted with chemicals and chemical waste before 1976, *or*
- a former landfill site put in operation before 1974 and closed down not later than 1990.

A site is contaminated if there is a threat to human health and/or the environment (groundwater, surface water, flora, fauna). Most of the sites covered by the Contaminated Sites Act are orphaned sites, and all measures are financed by the public authorities.

As a result of the last amendment of the Act on Contaminated Sites (July 1996), the 16 regional counties are responsible for the practical work. The Danish EPA’s role is primarily concentrated on providing guidance for the regional counties’ work and initiating and supporting technology development of methods for remediation of soil and groundwater.

The Deposits Council has been set up to advise the Minister on general matters concerning development of technology. The council will every year prepare a report to the Minister of Environment and Energy and the council will assess the overall need for technology development and will every year make recommendations for principles and program areas, including distribution of the appropriation on these areas.

The Loss-of-Value Act

As a supplement to the Act on Contaminated Sites, a special clean up system for land owners was introduced in late 1993 with the Act on Economic Blight to Family Housing on Contaminated Land. By paying a minor contribution, the home owner can initiate a publicly financed cleanup. The scheme was introduced to ease the problems for home owners and aid transactions on the real estate market. The budget in 1998 is 51 Mill

Dkr. (US$7.5 million). After a very slow start, the picture changed in 1996, where it was not possible for the authorities to comply with all the applications for remediation.

The Environmental Protection Act

This Act lays down the framework for control of polluting activities of active companies and empowers the authorities to carry out inspections and to enforce orders etc. Investigation and clean-up of contaminated soil and ground water can therefore take place by an administrative order. It is worth noting that the orders pursuant to the Environmental Protection Act can be addressed to an operating company only. If the company is not the polluter, the authorities must start proceedings against the polluter under civil law.

According to the Environmental Protection Act , the polluter is held responsible for remediation costs. Orphaned sites after 1974 represent an unregulated area in so far as they are not owned by the person or company who has caused the pollution. This means that the local authorities must finance remediation of these sites.

New Act on Soil Contamination

In 1994 the Minister for Environment and Energy set up a “Contaminated Land Committee”. In March 1996 the committee submitted a report on contaminated land, with a proposal for a revised act on contaminated sites. A revised proposal was set out in a public hearing on February 6, 1998. A revised proposal is expected to be presented to Parliament in 1998 and includes a proposal for inclusion of all contaminated land in an act on soil contamination. The intention of the proposal is to expand the regulation from a single source view into an expanded source view and provide legislation covering all aspects of soil contamination, also including management of soil excavated and transported from one place to another. The five main topics are:

- The conclusions to be drawn from the fact that extended contaminated areas, as well as contaminated sites, are in existence
- New concept for mapping
- How to secure groundwater and population within a short time span
- How to secure an environmentally safe handling of contaminated soil
- How to accomplish the polluter pays principle (PPP)

According to the proposal the polluter pays principle will be the basic principle. No distinction will be made between contamination taking place before and after the mid-1970s. All contamination taken place before the new act comes into force will be subject to the same regulation. But according to the proposal there will be a difference for contamination taken place before and after the date of enforcement of the new legislation. Whereas contamination taking place after the enforcement of the new act will be subject to strict liability, the applicability of “the polluter pays principle” will regard contamination that has taken place before the enforcement only if it can be proved that the polluter was acting in bad faith at the time the polluting activity was taking place.

2. Registration of Contaminated Sites

Identification of contaminated sites in Denmark consist of the following steps:

Step 1. Mapping of potentially contaminated sites (desk studies of present and former land use, etc.)

Step 2. Preliminary investigations on sites (in order to demonstrate that the site is actually contaminated)—preliminary assessment of potential risks from the site
Step 3. Registration with and notification to the Land Registry

Before 1990, Registration could be made on a "valid suspicion," for example, on the basis of a specific land use. However, the mortgage institutions introduced credit restrictions, so it was necessary to make a statutory order (1993) concerning the need for preliminary investigations to demonstrate that the site is contaminated before Registration. Furthermore, the Act on Economic Blight to Family Housing, etc., on Contaminated Land was passed by Parliament.

In March 1997 3650 contaminated sites were registered, and the total number is expected to be 11,000. The total number of new and older contaminated sites is estimated to be about 14,000-15,000 sites. About 4,500 sites are assigned to areas with vulnerable water use (threat to drinking water) and about 2,500 sites are assigned to vulnerable land use (*i.e.*, residential areas, playing grounds etc.) In 1998, the total budget for registered contaminated sites is 300 Mill Dkr. (US$45 million) plus 51 Mill Dkr for the Loss-of-Value Act.

From 1993 until the spring of 1997, 4,400 preliminary investigations have been carried out. The total number of preliminary investigations for registered sites referring to the Contaminated Sites Act is estimated to 9,000-10,000. The investigation usually involves 2-3 soil samples and possibly 1-2 groundwater samples. Of the 3650 sites registered up to 1997, there have been remedial activities on 800 sites.

3. Remedial Methods

The order of priority for remedial action in Denmark is based on equal weighting to current land use and groundwater protection. Highest priority is given for highly mobile substances situated where the geological determined protection of the groundwater is limited. For current land use, priority is given to sites where there is possibility of direct contact with the contamination, either because the contamination is situated in the upper part of the soil or due affects to the potential indoor climate. Surface waters can be given a high priority, if the effects of contamination can be measured. Only very few cases of remediation with regard to surface waters have taken place in Denmark.

The present situation of cleanup and remedial technologies in Denmark can generally be described as follows:

- Methods applied as a matter of standard procedure are predominantly off-site methods.
- Methods for remediation of organic contamination are manifold, whereas the possibilities of remediating inorganic contamination are limited.
- Several methods are suitable for sandy types of soil, whereas few methods are suitable for clayey and inhomogeneous types of soil.
- Application of *in situ* techniques is difficult due to inhomogeneous types of soil in Denmark.
- Some of the most frequently applied methods change the original structure of the soil.
- Many *in situ* techniques have a long operating time.
- Documentation of the efficiency of *in situ* techniques is generally scanty.

For all *in situ* and on-site techniques pilot-scale tests for development of concepts and optimization of methods are deemed necessary. For biological methods, however, the primary requirement is deemed to be optimization of the methods.

On the basis of a review of the country priority procedures from 1992, 1993 and 1994, the remedial technologies proposed in the recommended cleanups of soil contamination are illustrated in Figure 1*. The figure illustrates the relative number of recommendations for each technology. The result in the figure represents 107 proposals for cleanups. Vapor extraction of landfill gas makes up to a relatively large part of the technologies recommended in the country priority procedures of 1992, 1993 and 1994. Beside this technology, publicly financed cleanups pursuant to the Contaminated Sites Act are primarily carried out by means of excavation of contaminated soil followed by off-site treatment and/or disposal.

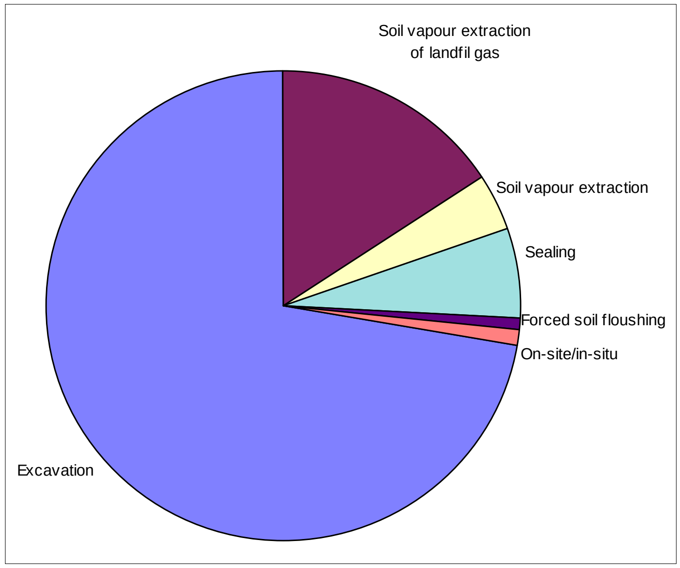

Figure 1. Technologies recommended for cleanup of soil contamination in the country priority procedures of the Danish EPA in 1992, 1993, and 1994.

Since 1994, the picture of technologies recommended for publicly financed cleanup of soil contamination has changed, especially the number of *in situ* remedial activities has increased. The same report shows that composite contamination has been identified in approximately 50 percent of the sites represented (excluding cases involving landfill gas). Thus, the proposals for cleanup focus to a great extent on handling of composite contamination and not just on handling of single-type contamination.

The choice of remedial technology is consequently often based on the fact that several types of contamination, often typically with very different physico-chemical properties, have to be handled in the specific cleanup operation. The Oil Petroleum Cleanup Fund has lead to optimization of clean up of oil pollution at former petroleum site.

4. Research, Development and Demonstration (RD&D)

The Act on Amendment of the Contaminated Sites Act introduces a scheme for development of technologies for cleanup and remediation of soil and groundwater contamination. The *Program for Development of Technology, Soil and Ground Water Contamination* has been established as part of this scheme. The program has an annual budget of 15 million DKK (US$2.3 million). The program lists several areas towards which the development of technology should be aimed during the coming two to five years.

The objective of the Program for Development of Technology is to target the development of technology towards the areas with the greatest environmental and health problems on the one hand. and areas in which great financial means are applied for remediation on the other. A great many criteria are assessed in connection with the identification of areas towards which the development of technology should be aimed, such as contamination components, soil and groundwater types, different types of contaminated industrial sites, frequent types of contamination, and composite contamination.

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* *Barriers to Development and Application of New Remedial Technology*, Project No. 21, 1996. Danish EPA.

On the basis of these assessments the following list of subjects towards which the technology program should be aimed has been elaborated:

- Soil and groundwater contaminated with chlorinated solvents.
- Soil contaminated with heavy metals.
- Soil and groundwater contaminated with oil/petrol.
- Soil contaminated with tar/PAH.
- Soil contaminated with composite contamination.
- Landfills with leakage of landfill gas.

Other activities towards which the technology program should be aimed and listed:

- Intrinsic bioremediation.
- Testing of computer modelling tools.
- Assessment of indoor climate problems caused by soil and groundwater contamination.
- Physical enclosure of horizontal dispersion of contamination.
- Testing of pavements and liners for construction on contaminated soil.

In accordance with the project proposal for 1996 and 1997 the technology program includes several field projects and several studies.

The purpose of the field projects is to carry out field tests to test and document a number of methods under Danish conditions. The results of the field tests are to form the basis of recommendations from the Danish Environmental Protection Agency concerning the application of the methods in question under Danish conditions. Field tests of the following methods for cleanup and remediation of soil and groundwater contamination have been given priority:

- Air sparging for cleanup and remediation of contamination in saturated zone with chlorinated solvents and light petroleum products such as petrol, kerosene and turpentine.

- Soil vapor extraction for cleanup and remediation of contamination in unsaturated zone with chlorinated solvents and light petroleum products such as petrol, kerosene and turpentine.

- Reactive permeable walls for removal of contamination with chlorinated solvents from ground water passing through the walls.

- Other field tests.

In addition, the following studies have been given priority:

- Review of methods for handling of soil contaminated with heavy metals.
- Bioventing with intermittent supply of air.
- Compilation of results from pilot projects carried out under the previous gas works scheme of the Danish Environmental Protection Agency.
- EU project on environmentally appropriate remediation of contaminated sites.
- Bioremediation.
- Joule heating (ERACE). Removal and degradation of volatile and slightly volatile substances by applying voltage.
- Other studies

5. Conclusions

Looking back over the past 15 years, Danish policy seems to be changing from a very idealistic approach (clean up of all contaminated sites, making them, wherever possible, clean/uncontaminated) to a more pragmatic approach. One of the reasons is the realization of the extent of the problem, as well as better understanding of the phenomenon. This does not mean that contamination/pollution should be accepted, especially not recent pollution, but it means there might be some sites where Denmark achieves the "most environmental benefit for least money" by making sure that there will be no exposure from the site. Current projects with relevance to risk assessment are primarily two projects carried out for the Danish EPA.

Many countries have technology programs that aim to reduce barriers by providing, for example, reliable data on performance and cost, translation of laboratory-scale technologies to technologies implemented at full scale, improve investor confidence in new technologies, and deal with technical barriers,

Reducing other barriers, and thereby providing for a wider use of the various treatment technologies, however, will also provide the technology programs with such initiatives as guidelines for target criteria for remedial actions (including acceptable residual concentrations left after treatment is ended), documentation of remediation, and affect policies such as landfill disposal of contaminated soil[*].

The trend of "back to nature" and simplicity might also influence the choice of remedial technology; phytoremediation and natural attenuation illustrate this tendency.

In relation to technology choices, it seems that long-term remedial activities is given high priority, meaning that short-term solutions (like solidification, etc.) will become less attractive.

In situ activities will continue and be expanded even more than at present. Implementation and prevalence of new technologies will increase. An example is reactive permeable walls. In a few years since its introduction, many countries have either implemented this technology, scaled up from laboratory to field test to full scale, or are already running full scale projects (helped, of course, because it is a "simple technology," which is very suitable for field tests).

Methods for treatment of soil contaminated with heavy metal seem to cause problem and so does handling remediation of composite contamination. Aspects like costs of operation, monitoring, life cycle analysis, sustainability, etc., will also have considerably weight.

From being a engineering phenomenon, remedial activities will become multidisciplinary, involving different scientific specialties; already biology and chemistry are involved, but in the future even more interdisciplinary themes will be necessary.

However, no matter what the future bring, excavation will always be necessary.

[*] Summary of Barriers Studies and Examples of Technology Programs for Development of Innovative Remedial Technologies. *Ad Hoc* International Working Group on Contaminated Land, Informal Working Group on Technology Choices, May 1997.

FINLAND

1. Legal and Administrative Issues

In the Report to Parliament on Environmental Protection given by the Council of State of May 31, 1988, is the following statement to the policy on contaminated sites in Finland:

> *Studies will be made of contaminated land areas, and steps will be taken as necessary to clean them up systematically. The most urgent reclamation work will be investigated as soon as the need for it is established. The following measures will be necessary to achieve this objective: appropriate administrative arrangements must made in the environmental authorities; techniques must be investigated and organized; and, where necessary, work must begin on revisions in legislation. As far as possible, the Polluter Pays Principle will be held to in meeting costs.*

Finnish legislation of primary importance in connection with soil contamination are, firstly, waste management legislation and secondly public health legislation and water legislation. There is no separate Act concerning soil protection or remediation of contaminated soil.

The Waste Management Act is the main legislative remedial tool for soil cleaning in older sites (created prior to January 1, 1994). According this Act, contaminated soil has been defined as waste, and the responsible parties are defined as the polluter, owner, or occupier of the property. In such cases where it is impossible to find a property owner or occupier, the municipality has the responsibility of risk assessment and remediation.

Soil conservation has been included in the new waste legislation (The Waste Act, in force since January 1, 1994) as a separate chapter. In the Waste Act, new soil polluting activities will be prohibited, or the soil must returned to its original state so that it can be used to any purpose to which it could have been used without the contamination. The Waste Act will also give the owner of property a responsibility to find out the state and contamination of the property and to transfer this information to the buyer. The Act will also enable the State Council to give detailed regulations concerning soil contamination.

There is also other legislation as those for public health, air pollution, construction and neighbor relations including certain licensing procedures. Water legislation prohibits pollution of ground and surface waters.

The Construction Act requires that land areas prejudicial to health may not be used for build on. The existence of soil contamination must be known whenever land use is planned.

The Environmental Damage Act came into effect in June 1996. It is applied to new environmental damages and based on the polluter pays principle. There is also a need for the complementary scheme for secondary compensation of the damages. The secondary compensation is based on the compulsory insurance (new law in 1998).

The Waste Act Section 22 sets an obligation on *"Prohibition on soil contamination and notification of contamination*." According this section "No waste or other substance shall be abandoned, discharged or deposited in soil in a manner resulting in such degradation of soil quality as may cause hazard or harm to health or the environment, significant decline in amenities, or other infringement of public or private interest (prohibition on soil contamination).

Whosoever operates or acts in a manner which may cause soil contamination shall adequately and effectively prevent the waste or other substances from entering the soil with the consequences referred to above. If the soil becomes contaminated, the party whose action has given rise to the contamination shall without delay notify the municipal environmental protection committee thereof."

Section 23 sets the *duty to clean contaminated soil*: "Whosoever operates or acts in a manner or likely to cause soil contamination shall investigate the need for cleaning or state of the site as required. If this investigation shows that the soil is contaminated, the contaminator shall as necessary clean the area sufficiently to ensure that it no longer result in the hazard, harm or other consequence referred to in section 22, paragraph 1.

If the contaminator cannot be ascertained or reached, or if he fails to comply with his cleaning duty, and the action resulting in contamination has taken place with the consent or knowledge of the holder of the site, or if this person was or should have been aware of the condition of the site when it came into his possession, the holder of the contaminated site shall carry out the action referred to in paragraph 1. If, in the case referred to in paragraph 2, the holder of the contaminated site cannot reasonably be ordered to clean it, the municipality shall similarity investigate the need to clean the site, and clean the site."

Section 24 addresses the *ordering cleaning of a contaminated site*: "In accordance with section 23, the regional environment center can require the contaminator or the holder of the contaminated site, or the municipality, to investigate the need to clean the site and to clean it, and issue the regulations and directives needed to this end."

Section 25 sets the *duty to give account of contaminated sites*: "Whosoever sells or otherwise assigns the title to or leases a land area shall provide the new holder of the area with any information available on the activities formerly practiced in the area, the wastes or substances that exist in the area, and whether the soil has been shown to be contaminated or whether there are wastes and substances in the soil which may lead to soil contamination"

Finnish environmental laws, especially waste legislation, are powerful instruments and it is used successfully by authorities in remedial actions of contaminated soil in recent years.

The Ministry of the Environment is the national environmental authority. It formulates environmental policies and does strategic planning. It is also responsible for preparing legislation, setting binding standards and allocation of public funding.

The regional environmental administration is proved by 13 Regional Environmental centers. They are responsible for data collection and allocation of public funding. They create and run clean-up programs, give permits for all clean-up works and make plans for remediation (called state waste management works).

The Municipal Boards for Environmental Protection supervise local environmental affairs.

The Finnish Environment Institute conducts environmental R&D. It provides independent expertise for the identification, assessment, clean-up and control of chemically contaminated environments including contaminated soil.

At the moment urgent remedial works will be carried out without waiting for the priority plans of contaminated soil remediation.

Contaminated soil areas will be cleaned until year 2015.

The private sector is carrying on the clean up actions on its own contaminated sites.

Restoration of old, abandoned sites is funded by budgeted financing and carried on by authorities. There is a state waste management system that makes it possible for the state to participate or finance (on average by 50 percent) remedial action in co-operation with the municipalities.

The oil sector, municipalities, and state made an agreement in 1996 for 10 years dealing with cleanup of contaminated gasoline stations, which will be or have already been closed. The program is based on an agreement among the Finnish Petroleum Federation, the Ministry of the Environment, and The Association of Finnish Localities. It is being funded by main oil industry marketing companies, as well as the Oil Pollution Compensation Fund, operating in connection with the Ministry of the Environment, to which oil companies pay a fee levied according to their oil imports to Finland. Oil sector will pay the clean up costs of their own stations and Oil Damage Fund will pay the actions needed on the abandoned gasoline stations.

Soil contamination will to be taken into account in land use plans and land use changes in larger extent. At the moment there are not so called Brownfields in Finland.

2. Conclusions

Problems are at the moment: in practice resourceless liable parties, question of optimizing the cleanup projects, quality assurance of plans and actions and last but not least fast growing rate of cleanup sector.

Until now, common remediation methods used in Finland are composting, stabilization, purification of the pore air of soils, containment, incineration in high or low temperature, disposal of slightly contaminated soils at landfills and also ground water treatment. Washing techniques and biological *in situ* methods have not been applied at full scale.

Research and development work is being carried out with composting of soil contaminated by oil and chlorinated phenols, purification of soil contaminated by dioxins and furans (containment, incineration, biological decomposition), use of fungi for aerobic decomposition, use of plants (vegetation) in the clean-up of polluted soil and biological filters for the gases from pore air purification, consolidation and stabilization techniques, as well as biological *in situ* treatment of soil and ground water.

Soil protection, including soil contamination as well as other conservation and degradation processes, is now viewed in general terms. The condition, loading, and protection of soil in Finland has been investigated. Major and irreversible degradation of soil has been avoided so far. The next step will be a target program for soil protection. Also, local and regional soil protection projects have been discussed.

The Finnish legislation is at the moment the powerful instrument for remedial actions of contaminated soil, and the Council of State will issue more detailed regulations concerning the implementation of provisions on soil contamination. Under consideration is a draft to target and limit values of concentrations of harmful substances in soil.

The cooperation between central and regional authorities and the private sector is ongoing in the oil sector, as mentioned above, but also in such others as the forest sector, which is cleaning up old sawmill sites contaminated with organochlorinated compounds. The private sector is carrying on the clean up actions on its own contaminated sites. Restoration of old abandoned sites is funded by budgeted financing and carried on by authorities. Financial responsibility can also be apportioned between state and private parties if necessary, for example in cases, where the requirement to restore the site would be unreasonable severe.

FRANCE

1. Legal and Administrative Issues

It may be considered that the French policy in matter of polluted land has been defined in its general features and objectives by the December 3, 1996, circular letter of the Minister of the Environment. This policy can be characterized by a will of efficiency and realism. The circular letter includes a paragraph entitled, "*The principles of a realistic policy for the treatment of polluted sites and soils*," in which it is written that "*...it is a long term action, to the scale of the century and half of industrial history of our country. The development of this policy can only be progressive and according to the public and private means that will be possible to mobilize...*"

Another aspect of this policy is the principle of dialogue, also mentioned in the circular letter of December 1996. This principle is put in practice between the Ministry of the Environment and the different actors that take part in the management of polluted sites: governmental agencies (ADEME, Water Agencies), industrial operators of potentially polluting installations, associations for the protection of the environment, experts, consultants and enterprises specialized in evaluation and treatment of polluted land and, in the case of pollution related to domestic waste, Municipalities and Territorial Institutions. There are different circumstances where this dialogue may occur. At the national level it is existing in the two committees that have been created for the management of the funds supplied by the waste taxes, and in the national working groups that discuss the projects of methodological guides prepared by the Ministry of the Environment, before these guides are issued as references for technical regulations.

In the case of polluted sites, the basic legal reference is the law of July 19, 1976, on the Installations Registered for the Purpose of Environmental Protection (*Installations Classées pour la Protection de l'Environnement*: IC Law) which covers all environmental aspects of industrial activities (including waste management and treatment or disposal). According to this law industrial installations have to be either authorized (if they have potentially a strong environmental impact) or declared (if they have potentially a little environmental impact). Another basic reference which may be applied in the case of pollution of land is the law of July 15, 1975, on elimination of waste and recovery materials (*Elimination des Déchets et Récupération des Matériels*: Waste Law). Additional laws improving the management of the environment complete the I.C. and waste laws:

- The Law of July 13, 1992, created a new policy for the management of domestic wastes including:
  - the progressive banishment of direct landfilling of waste within a time limit of ten years,
  - the institution of a tax on the direct landfilling of domestic waste,
  - a specific section on the selling of industrial land, where installations regulated by the IC Law have been operated, that oblige the vendor to inform the purchaser of the possibility of the pollution of the considered land. In this situation the purchaser has the possibility to cancel or to renegotiate the sale.
- The Law of February 2, 1995, regulated the procedures in the case of "orphan" polluted sites and finance this action by the extension of the waste tax (law of July 1992) to special (polluting) industrial waste treated or disposed in collective installations.

In connection to these laws additional legislative decrees and circular letters (directives) have been issued, mainly:

- The decree of September 21, 1977, that defines the obligations of the operator of an industrial installation in the case of cessation of activity

- The circular letter of December 3, 1993, defining the policy for polluted sites

- The circular letters of April 3 and 18, 1996, requiring the realization of preliminary diagnostic and simplified risk assessment for active industrial sites

- The circular letter of June 7, 1996, describing the procedure to be carried out to apply the polluter pays principle.

At the origin, in 1978 and during the eighties problems of polluted sites and soils were systematically related with problems of wastes.

A wider concept of pollution of land designated by "polluted sites and soils" was introduced at the beginning of the nineties. Accordingly, on December 3, 1993, the circular letter dealing with the "policy of rehabilitation and treatment of polluted sites and soils" was issued by the Minister of the Environment and gathered the main elements of a new policy for the subject encompassing:

- a systematic registration of potentially polluted sites
- a concerted definition of priorities
- the treatment of every polluted site according to its impact and the use of the land.

At the present time, a polluted site is defined as a site generating a risk—either actual or potential—for human health or the environment related to the pollution of one of the media, resulting of past or present activities. In practice, polluted sites are industrial sites, active or inactive, waste sites, accidental pollution sites.

Although there is a recent tendency towards some regionalization, France remains a centralized country. For the environment, like for other subjects, laws are discussed and voted by the parliament and regulations are enacted by the Government and have a national validity. At the central level, the Ministry of the Environment is responsible for the management of the environmental policy. More precisely, inside the Ministry of the Environment, the Department in charge of industrial pollution and waste management, including the problem of polluted sites is the Direction of Prevention of Pollution and Risks (*Direction de la Prévention des Pollutions et des Risques*: DPPR). At the local level the basic geographical administrative unit is the department (there are 99 departments in the country), and in every department, the Prefect, who is the representative of the government, is responsible for the implementation of the regulations. In the particular case of polluted sites, for which, the basic framework law in the Law on Registered Installations (IC Law, mentioned above in b). The Prefect is assisted by the Inspectors of the Registered Installations who control industrial activities (including waste management and disposal) and who are in almost all cases members of the Regional Direction of Industry, Research and Environment (*Directions Régionales de l'Industrie, de la Recherche et de l'Environnement*: DRIRE).

Basically the legal and administrative action is based on the polluter pays principle, the polluter being, according to the IC Law, the operator of the installation at the origin of the pollution.

The circular letter of the Minister of the Environment of June 7, 1996, gives a detailed definition of the procedure to be carried out by the authorities to manage the suspected or proven contaminated sites according to the polluter pays principle and, in case of failure, to deal with the orphan sites. This procedure may be explained as follows: in the case a registered installation is suspected to be responsible of land pollution, the Prefect may require the operator, according to the IC Law (section 23), to carry out the actions (investigations or clean up) requested by type Inspectorate of Registered Installations (*Inspection des*

Installations Classées). If the operator does not comply with the order, the Inspector of the Registered Installations writes to the Prefect a certified report assessing this non execution. In this situation, the Prefect may require the operator to deposit to a public accountant a sum representing the estimated cost of the requested work. If this procedure does not succeed, most of the time because of insolvency of the operator, the public accountant states the insolvency of the responsible party to the Prefect who will then send the file of the considered case to the Ministry of the Environment, requiring the site to be considered as "orphan." If the Ministry agrees, the case is presented to the specific National Committee to be financed by public funding (waste tax). Then, if the case is accepted by the Committee, the Prefect is allowed to issue an order asking ADEME to carry out the requested investigations or clean up. After the requested actions have been carried out ADEME has to initiate lawsuits against potential responsible parties in order to try to get the reimbursement of the public money spent for the case.

The position of the authorities concerning the owner of a polluted site is a subject of active discussion. Some years ago, the position of the Ministry of the environment was rather to consider the owner as a responsible of second row and generally no action was initiated against him. Now this position has changed and the Ministry requires the Prefect, in the case of failure of the action against the operator of the installation, to engage lawsuits against the owner. However the existing jurisprudence is rather controversial and the legal validity of the Ministry's new position is not proven.

As it has been explained above the French approach to deal with polluted sites is basically connected with the legislation on the environmental management of industrial installations (IC Law) and to a more limited degree to the management of waste (waste law).

This means that these is no specific legislation relative to soil protection or polluted sites. Although the development of such legislation has been already considered, it seems that it will probably not happen in the short or middle term and that the existing approach will continue.

In this view the existing laws (IC Law) will be applied and completed by technical directives (circular letters) issued by the Ministry of the Environment to organize the management of polluted sites. These technical directives are related to technical guides developed at the present time.

A first technical guide has been issued in 1996 (draft 0) and 1997 (draft 1) to organize the preliminary evaluation and priority ranking of suspected polluted sites. The proposed preliminary evaluation includes two steps:

- Step A: A documentary study (a historical review and a vulnerability study) based on available and accessible data, and is completed with a site visit. The historical review includes a description of the sequences of activities that have taken place in the course of time, their precise locations and any associated environmental practices that may have been carried out. The vulnerability study includes an investigation of the parameters (geology, etc.) that could have relevance for the fate and transport of the contaminants and the potential targets (housing, drinking water supply, etc.) likely to be affected.

  During the site visit the data deriving from the documentation study should be verified and additional data acquired. An evaluation and identification of existing and potential impacts takes place and a further investigation program is prepared.

- Step B and the simplified risk assessment (SRA) includes the collection of data that have not been available within the previous study but are conditional for the simplified risk assessment. The SRA demands an understanding of the contamination's spatial distribution and transport mechanisms, the identification of possible hazards and the description of possible rehabilitation methods. At this stage it is necessary to develop some field investigation in order to acquire the data that make this understanding possible.

Based on the results of the preliminary evaluation, a simplified risk assessment is conducted according to a scoring system the site in question is classified in one of three groups:

- sites needing further investigation and detailed risk assessment
- sites for which monitoring systems should be applied
- sites that can be used for specific purposes without further investigations or implementation of measures

The decision making process within the SRA is supported by defines guideline values.

At the present time, another methodological guide is in preparation, under the responsibility of the Ministry of the Environment, in cooperation with a national working group. This guide will define the objectives and contents of the impact study (detailed investigations) and detailed risk assessment.

For the sites where the preliminary diagnostic concludes that the pollution and risks are serious, the realization of the impact study and risk assessment will give the basis to determine the rehabilitation objectives and to select the remedial options.

2. Registration of Contaminated Sites

Although France was probably one of the first countries to carry out some kind of inventory of polluted sites, limited attention has been given to the problems of land pollution until the beginning of the nineties. A part from the initial national surveys on contaminated sites conducted in 1978, new activities have been taken recently.

National register

At the national level, since 1993, a national register is managed by the Ministry of the Environment (DPPR). In this register are gathered the sites that are known by the local authorities and can be considered as polluted.

These sites are listed in a computerized database and reports are periodically issued by the Ministry to inform the public of the situation. A publication of this register was issued in December 1994, gathering 669 sites. Another one based on the situation of December 1996 was issued in Decemeber 1997, with 896 polluted sites, plus 125 sites already restored without any limitation of use.

Inventories

In connection to this registration system are the actions of inventory carried out through two specific ways:

The historical inventories, initiated at the regional level, based of the consideration of local industrial history in order to discover, in connection with the existence of past polluting industrial activities, the places where pollution can be suspected. These inventories are mainly based on the consideration of the archives and indicate suspected sites (or potentially polluted sites). At the present time (end of 1997) about half of the departments located in 17 regions have initiated such inventories. It is expected that about 200,000 to 300 000 suspected locations will be collected at the end of these studies for the whole national territory among which some thousand will require corrective action.

The evaluation of the pollution of active industrial sites (including industrial waste treatment and disposal sites)

In April 1996, the Ministry of the Environment instructed the Prefects of the departments to draw up a list of priority sites as a first step to further investigation of these sites. A preliminary classification of priorities is given in the annex of the circular letter. Within 5 years it is previewed that some 1,500 to 2,000 sites assigned with priority I will be listed for further investigations.

Estimation of the number of polluted sites

The two previously mentioned actions, historical inventories and evaluation of active industrial sites, are not enough developed to allow a significant evaluation. The only very approximate estimation possible at the present time is 200,000 to 300,000 suspected sites and some thousands of cases requiring corrective actions.

3. Remedial Methods

According to the data collected in the national register published in Dec. 1997, the techniques used for the polluted soils in the sites were a rehabilitation project has been carried out can be listed as follows:

- Landfilling 44
- On site isolation 60
- Stabilization 12
- Natural attenuation 15
- Biotreatment 29
- Soil washing 10
- Thermal/incineration 29
- Other 33

In more than one-third of these cases, combinations of techniques have been used.

For the first cases of rehabilitation during the eighties and in the beginning of the nineties, most of the techniques used were isolation and treatment or disposal in the installations of the waste system.

It appeared soon that waste treatment plants (incineration) were often technically inappropriate and very expensive and, because of recent regulations, inducing restrictions of use and technical constraints, landfilling has become more and more difficult and costly.

These circumstances create a positive evolution for the use of specific soil treatment techniques.

Isolation remains one of the most frequently used techniques, mainly in cases where no treatment technique can be technically or economically applied.

The techniques that have been and are still the most frequently used to clean soils are microbiological degradation and soil venting.

Biodegradation is most of the time carried out on site by the mean of composting or bio-piles. Contaminants degraded are petroleum compounds, light and heavy oils, and even polyaromatic hydrocarbons. Soil venting addresses volatile hydrocarbons and chlorinated solvents in the unsaturated zone. It is sometimes associated with *in situ* biodegradation (bio-venting). To remediate the saturated levels, (groundwater) venting is combined with air sparging.

More recently, new treatment capabilities have been made available either by specific own development or by technology transfer. The techniques concerned are soil washing (solvent washing) and thermal desorption.

At the present time, four thermal treatment installations, with various level of performance (quantity and complexity of pollution that can be treated), have been made available in France and a fifth is under consideration.

4. Research, Development, and Demonstration

The support of R&D by the Government is mainly provided by the Ministry of the Environment and the Ministry of Research and Education through three different ways:

- Ministry of the Environment, Section in charge of Research and Economic Affair (SRAE) that develops research programs focusing on behavior of contaminants in regard of risks and possibilities of treatment.

- Ministry of the Environment, Section in charge of Industrial Environment (SEI) that develops the methodological guidance documents to be used in connection with regulations.

- Agency of the Environment and Energy Management (ADEME) in charge of evaluation and rehabilitation of orphans polluted sites that develops specific research programs to improve the basis of decision making procedures and to optimize the choice of remedial techniques and the control of their efficiency.

The total amount of funds made available through these three actions is about 12 Millions FF/year.

Concerning the development of rehabilitation techniques some public money is supplied by the Ministries of Research an of Industry through funds to help technical innovation and international cooperation (EUREKA projects).

In addition to governmental funding, some support to R & D projects are also provided by Regions most of the time in connection with the economical redevelopment of brownfields (North or Lorraine Regions).

In addition to research programs financed by publics funds, some enterprises develop specific R&D activities. These enterprises can be gathered into two categories:

- Enterprises responsible of polluted sites that are looking for optimization (technical and economical) of the management of these sites: a typical example of such enterprises in Gaz de France that is in charge of about 450 gaswork sites.

- Enterprises that are active in evaluation and/or clean up of polluted sites and that try to improve their know how.

According to the present situation, it can be estimated that the R&D programs are mainly oriented in two directions:

- Increase the efficiency of the management of the suspected and proven polluted sites by the preparation of technical guidance documents associated with the development of specific tools to improve the decision making procedures

- Develop more economical and efficient equipment and processes to characterize and to treat the pollution.

Considering the treatment techniques, two possibilities are simultaneously developed:

- Improvement of existing techniques: a typical example is bioremediation with many projects trying to extend its application to recalcitrant pollutants (PAH, PCB, etc.).

- Development of new treatment techniques: reactive walls, supercritical extraction, electromigration.

GERMANY

1. Legal and Administrative Issues

According to the German Constitution, the 16 Federal States are responsible for the contaminated site remediation. For the enforcement of the contaminated site remediation, which includes the steps registration, assessment and remediation in general, the Federal States have enacted specific legislation. In the framework of the Federal State's laws regulating the contaminated site remediation, different criteria and values are currently used. Together with these regulations more than 35 different lists containing values such as soil screening, action, and clean-up values exist all over the country. As these values differ more of less from each other depending on different derivation criteria, harmonization and standardization is still urgently needed.

Therefore, the Federal Government submitted the Federal Act on Soil Protection and Remediation of Contaminated Sites (Bundes-Bodenschutzgesetz) to the Parliament in 1996. In February 1998 the Federal Soil Protection Act was passed by the Parliament and the Federal Council. The Act is expected to come into force in March 1999, after the sublegal regulations have been finalized.

The Federal Soil Protection Act (SPA) includes precaution issues as well as remediation of contaminated soils and sites. The main purpose of the SPA is to protect against harmful changes in the soil. Harmful changes in the soil exist when the soil functions are impaired, and when this becomes dangerous, leads to adverse effects for individuals or the general public. The definition of the SPA includes natural soil functions and functions of the soil utilization.

Following basic duties guarantee that the soil as living basis for human beings, animals, plants and soil organisms will be maintained and secured for future utilization:

- Preventive duties exist that the soil is not demanded too much in its ecological efficiency by material and physical influences,
- existing harmful changes in the soil which cause dangers to human beings and the environment have to be remedied. The duty for remediation also includes groundwater pollution which is caused by the contaminated soil,
- site owners are obliged to take care that no hazards are caused by the site conditions,
- everyone has to behave in such a manner that harmful changes in the soil do not occur.

The two terms harmful changes in the soil and contaminated sites in the SPA cover all burdens of the soil that cause hazards for human beings and the environment. Contaminated sites (CS) are defined as—

- closed-down waste disposal facilities or other estates on which wastes have been treated, stored or disposed (abandoned waste disposal sites - AWDS); and
- estates of closed-down facilities and other estates on which environmentally hazardous substances have been handled (abandoned industrial sites - AIS).

—that cause harmful changes in the soil or other hazards for the individual or for the general public. Sites which are suspected to be contaminated (SCS) are by definition of this law AWDS and AIS which are suspicious for harmful changes in the soil or other hazards for the individual or the general public.

The following regulations for the remediation of contaminated sites are a substantial part of the SPA:

- Federal States' (Länder) authorities are responsible for registration, investigation and assessment of SCS.
- Authorities may require under certain conditions, remedial investigations and a remedial plan by those who are obliged for remediation.
- The remedial plan should be a straightforward, even in cases of serious and complex contaminated sites, in order to gain the acceptance of the necessary remedial measures by the affected persons.
- The remedial plan should cover a summary of the risk assessment and the remedial investigations as well as the remedial goals and the remedial measures.
- By regulation, the remedial plan is prepared by an expert.
- In the cases of CS and SCS, responsible persons are obliged to announce these sites and to carry out self-control measures; the authorities are responsible for the supervision.
- Together with the remedial plan, the regulated person can submit a public contract for the remedial measures.
- To enhance the approval procedure the official obligation of the remedial plan as well as the official order for remediation concentrates all necessary permissions from other laws.

2. Registration of Contaminated Sites

The registration of suspected contaminated sites (SCS) which is carried out by the Länder, is focused on the registration of abandoned waste disposal sites (AWDS) and abandoned industrial sites (AIS). As a result of a nationwide survey in 1997, more than 190,000 SCS were registered, nearly 90,000 are AWDS and more than 100,000 are AIS. The registration is not finished yet. The estimated number is that more than 240,000 SCS will be registered in the future.

Table 1 represents the status of inventory of SCS excluding military sites and armament production sites. Due to the different definitions of SCS in the Länder according to their legal regulations the numbers can hardly be directly compared. For example in Hesse, suspected contaminates sites are sites with proven contamination. In Lower Saxony and Rhineland Palatinate no numbers (k.A.) are available yet. In Lower Saxony between 35,000 and 50,000 AIS are expected.

In addition to contaminated sites which were caused by civil site use, Germany is dealing with former military sites which are contaminated by military operations and installations after the Second World War.

Until 1995, on the 1,026 WGT-Bases with a total area of 256,000 hectare 33,738 suspected contaminated sites have been registered. As result of a preliminary assessment 12 percent require immediate action, 32 percent require further medium-term investigation and 56 percent are not environmentally relevant. Most of the sites were handed over to the Länder in East Germany.

The end of the cold war, the dissolution of the former Soviet Union, the withdrawal of the West Group of the former Soviet Troops (WGT) from East Germany and the significant decrease in the number of active military personnel and installations of the Allied and German forces results in around 500,000 hectares of former military land which is returned to civil control and reuse.

Table 1. Inventory of Suspected Contaminated Sites in Germany (December 1997)

Federal States	Registered Suspected Contaminated Sites		
	Abandoned Waste Disposal Sites	Abandoned Industrial Sites	Sites in All
Baden-Württemberg	5,008	1,886	6,894
Bavaria	9,549	3,029	12,578
Berlin	615	5,068	5,683
Brandenburg	6,410	8,932	15,342
Bremen	100	3,000	3,100
Hamburg	446	1,080	1,526
Hesse	145	347	492
Mecklenburg-Western Pomerania	2,810	5,890	8,700
Lower Saxony	8,656	k.A.	8,656
North Rhine-Westphalia	16,689	11,640	28,329
Rhineland-Palatinate	10,578	k.A.	10,578
Saarland	1,801	2,442	4,243
Saxony	9,211	21,120	30,331
Saxony-Anhalt	6,742	12,716	19,458
Schleswig-Holstein	3,069	14,177	17,246
Thuringia	6,226	12,003	18,229
Germany total	**88,055**	**103,330**	**191,385**

The remaining 380,000 hectares still belong to the Federal Government. On behalf of the Federal Ministry of Defence, the Federal Ministry for Construction and the Federal Ministry of Finance, the Finance Office in Hannover is coordinating further activities on these sites.

Former armament production sites are sites which have been contaminated during World War I and II by ammunition production facilities, depots, delaboration works and storage of chemical warfare agents. As a result of a nationwide inventory, 3,240 suspected former armament production sites were registered. The assessment of these sites which is conducted by the Länder is not finished yet.

3. Remedial Methods

According to the definitions of the Federal Soil Protection Act remediation are measures—

1. For the removal or reduction of contaminants (decontamination measures);

2. That prevent or reduce the spreading out of contaminants on a long-term basis without removing contaminants (safeguarding measures); or

3. For the removal or reduction of harmful changes of the physical, chemical and biological nature of the soil.

As the Federal States (Länder) and the local communities are responsible for the remediation, there is no nationwide overview on used technologies available. In 1996 an evaluation for the Federal State of Northrhine-Westphalia on the applied technologies indicates that there is a significant trend towards containment techniques. From 660 applied remedial measures at 498 industrial sites 50 percent were excavation measures with subsequent disposal of the soil, 32 percent decontamination measures including pump and treat of groundwater and soil vapor extraction techniques, and 18 percent containment measures. Actual soil clean-up technologies (thermal treatment, soil washing, biological treatment) were 5 percent.

Due to the economical situation of the communities there is a common trend to use low cost technologies (containment, disposal) rather than more expensive decontamination technologies.

Contaminated soils are mostly treated off site in stationary treatment facilities. As of October 1997, 107 soil treatment facilities with a treatment capacity of 3.8 million t/y are available in Germany:

- 4 thermal treatment facilities (total capacity 168,000 t/y)
- 24 soil washing facilities (total capacity 1.5 million t/y)
- 81 biological treatment facilities (total capacity 2.0 million t/y).

In 1996 the total soil treatment capacity was about 3.5 million t/y; the average used capacity was about 64 percent. Fifty-six percent of the soil was treated by biological techniques, 39 percent by soil washing, and only 5 percent by thermal treatment.

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GREECE

1. Legal and Administrative Issues

Greece has taken positive legislative action for the protection of public health and the environment, and has included in its national legislation since 1986 the basic environmental law 1650/86, which covers all environmental fields and aspects. In this law, specific provisions are included, referring to soil protection from the disposal of municipal and industrial wastes, as well as from the excessive use of fertilisers and pesticides.

More specific legislation, concerning some aspects of contaminated land (soil and underground water) is included mainly in the following Joint Ministerial Decisions (JMD):

- J M D 26857/553/1988: "Measures and limitations for the protection of underground water and discharge of certain hazardous substances"
- J M D 69728/824/1996: "Measures and provisions for solid waste management"
- J M D 19396/1546/1997: "Measures and provisions for hazardous waste management"
- J M D 16190/1335/1997: "Measures and provisions for the protection of water from nitrate contamination of agricultural origin"

According to J M D 69728/824/1996 and 19396/1546/1997, waste management should be performed in such a way that the pollution of water, air, soil and generally of the ecosystem be prevented. The first J M D defines the obligations of the local authorities, regarding contaminated land from municipal waste disposal, as those authorities are responsible for municipal waste management, according to the national legislation. The second J M D prescribes, among others, the obligations of the producer/holder of hazardous waste, regarding contaminated land from hazardous waste disposal.

Following the provisions of J M D 69728/824/1996, the competent ministries have drawn up the national planning and issued the guidelines of the regional planning regarding municipal waste management. In the latter, one important issue is the registration of the uncontrolled waste dumps, and the gradual elimination through rehabilitation and reclamation. Other basic factors, which should be taken into account in the rehabilitation procedure, are:

- The final land use
- Geographical data
- The distances from houses, industrial installations, etc.
- The general character of the area (agricultural, grazing - lands etc.)
- The operation possibility of proper, local waste - transfer systems
- The ecological cohesion of the greater area.

Also, according to the legislation mentioned above, the person or carrier (*e.g.*, the local authority) responsible for waste disposal is charged with the cost of disposal site rehabilitation or reclamation, but in cases of orphan sites that cost is to be covered by public resources.

2. Registration of Contaminated Sites

No official survey or registry, or official guidelines exist in Greece regarding contaminated land. The land contaminated by industrial activities is rather limited, because of the lack of important heavy industry. Suspected sites are the Industial Areas of Athens (Thriassion Pedion, west of Athens, Oinofyta, north of Athens), Thessaloniki, Volos, and Kavala. Moreover, redundant or operating polymetallic sulphide mines are suspected sites (this includes the redundant mines in Lavrion, where heavy metal pollution has been documented, and other sites, as Thassos, Ermioni, where no studies have been done. In the operating Kassandra mines in N. Greece an extensive rehabilitation plan is under way).

Concerning landfills, the first inventory carried out in 1988 revealed that 1500 sites were operating with some rules, while 3500 sites were operating without any environment protection measures.

Since 1990, all new sanitary landfill sites should follow the procedure defined in the J M D 69269/5387/90 mentioned above. Local authorities are responsible for the municipal and household waste management. The waste disposal must be performed under control according to the environmental terms defined by the competent authorities and under continuous monitoring. Secondary landfill site should be rehabilitated at the end of the operation and the local authorities are responsible for the restoration costs. The redundant landfill sites, in which operations have stopped before 1990, cause serious pollution problems.

The hazardous waste produced in Greece is estimated to be around 450 000 tpa. The disposal of hazardous solid waste and sludge is done either in common landfill sites or in specific sites under control. Co-disposal is applied for those of the industrial wastes and sludges which have composition similar to the household wastes. Dangerous industrial waste are disposed of according to their origin and grade of risk posed. PCB's, cyanide wastes, pesticides, etc., either are stored in a safe place or they are exported for thermal decomposition according to the existing legislation.

The main contaminated areas in Greece include:

- The greater Lavrion area, 60 km SE of Athens. Intensive polymetallic sulphide mining and smelting activities practised for over 3000 years resulted in extensive contamination of land and groundwaters by heavy metals. Mining and smelting activities stopped in 1988. Urban expansion has lead to changes in land use from industrial to residential, recreational and, to a lesser degree, agricultural. An extended program is under way to define the pollution and develop remedial action.

- Thriassion Pedion, 20 km W of Athens. This is the main Industrial Area in Athens, with major industries (Refineries, Steel Plants, Shipbuilding, Cement Plants), as well as minor ones. Contamination of land and groundwater has been determined at various sites. The sea bottom sediments in the Eleusis Gulf are also suspected to be contaminated.

- Ano Liossia Landfill. Studies have been completed concerning biogas composition, groundwater contamination by leachates.

In the other industrial areas (Volos, Thessaloniki, Kavala) a limited number of data exist.

3. Remedial Action

Three rehabilitation projects on existing landfill sites are currently being undertaken:

- Ano Liossia Landfill site, Athens. This is the main municipal landfill of the major Athens Area and lies close to the Thriassion Pedion Industrial area of Athens. Leachates from this landfill seriously pollute the groundwater which eventually ends up in the Gulf of Eleusis. The rehabilitation studies have been completed and the works are under way.

- The environmental impact assessment studies have been completed for the now redundant Schistos landfill, which was serving the Piraeus area and stopped operating since 1992.

- Taragades landfill site of Thessaloniki. In this site the rehabilitation works have already started with the installation of pipe system for the collection of produced leachate and biogas. The cost of the above mentioned sanitation is about 100 million GRD and will be covered by co-financing between Greece and the European Union.

Relevant action is also planned or under way for other minor landfills or uncontrolled dumping sites in Greece.

A major project is under way for site selection and installation of two modern sanitary landfills for municipal waste to serve the greater Athens area. The main problem encountered is the public perception and acceptance of the proposed sites.

Two projects are under way for site selection and construction of plants for the controlled disposal of hazardous wastes from the northern and southern Greece, respectively. In addition, the installation of a treatment plant for liquid dangerous wastes and sludges produced from industries of Attica and Viotia Prefecture is under study. The major problem being faced here is, again, the public perception and acceptance of the proposed sites.

An extensive rehabilitation project of a sulphidic tailings dump has been completed in Lavrion, involving the addition of ground limestone to neutralise the acid generation potential, followed by an earth cover to isolate the toxic tailings from the environment and establish an aesthetic vegetative cover. More rehabilitation action is being undertaken on laboratory and demonstration scale, involving soil rehabilitation using chemical fixation as well as soil washing-leaching technologies.

Extensive rehabilitation projects are being carried out in the Kassandra mines, N. Greece, by the mine owner (TVX HELLAS), involving reactive sulphide tailings and acid mine drainage. The works involve physical and chemical stabilization of the material, as well as collection and treatment of the contaminated mine waters as well as leachates.

4. Research, Development, and Demonstration

A number of RD&D projects are being carried out in Greece regarding contaminated land. They aim either to identify the problematic areas, define the extent of pollution and its environmental implications, or to develop technologies for treatment and clean-up. The cost is covered by State, Municipal and EU funds.

Research carried out by the Laboratory of Metallurgy, National Technical University of Athens is focusing on: Development of methodology for the environmental characterisation of contaminated sites; soil rehabilitation by chemical fixation and leaching techniques; treatment of contaminated groundwater by active and passive systems; abatement of the acid mine drainage phenomenon. The activities are encompassing active and redundant mining and processing areas in Greece (Lavrion, Kassandra, Thassos), Italy (Sardinia), UK (Carnon Valley, Cornwall), Portugal (Estarreja), Bulgaria (Burgas Copper Mines), and Romania (Rossia Poieni Mines, Somova, Baia, Navodari).

Other research projects in Greece involve: determination of trace elements in crops within the Greater Thessaloniki Industrial Area; environmental impact assessment of the Assopos river valley; water resources and quality of groundwater in the West Attica Prefecture; oil and oil-dispersant toxicity in marine coastal areas; environmental toxicology; development of tools for the assrssment of groundwater contamination from biochemically reactive substances; risk assessment and soil rehabilitation methodology for the mining area of North Euboea; study of the quantity and transportation of asbestos fibres in Aliakmon River, N. Greece.

5. Conclusions

Land contamination in Greece is related to industrial activities as well as municipal landfills. No specific legislation or guidelines regarding soil quality standards exist. Registration of land affected from landfills has been done, but no registry exists for the industrially contaminated sites. Research carried out by Universities and Research Organisations have identified a number of industrially contaminated sites and studied technological solutions for rehabilitation. The research is funded through EC, State and Municipal grants. Municipal landfill rehabilitation has attracted considerable interest and many remediation projects are currently under way. However, very little attention has been given to industrially contaminated land. Although research has been carried out, application of the remediation solutions to full-scale is extremely expensive and has not been practised to any considerable extent.

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HUNGARY

Economic growth, especially vigorous industrial development, took place in Hungary without the constraints of strong environmental protection regulations up to the end of the seventies and the beginning of the eighties. Although the legal regulations concerning environmental protection later caught up with contemporary requirements, compliance with the regulations fell far short of the theoretical strictness of the limits and other regulations for a decade or so. In the midst of the economic difficulties of the time, only insubstantial amounts could be spent on environmental protection. This situation has led to a gradual accumulation of non-degradable and slowly degrading pollutants in groundwater and the soil.

There are approximately ten thousand polluted areas in Hungary where cleanup would have been an imperative for years, even decades. The environmental protection authorities, local governments, and possibly other organizations have information (which is far from complete) concerning only a fraction of these. The pollution of the soil and groundwater is obviously less perceptible than smoke-emitting factory chimneys, petrochemical city smog, or dead fish in oil-stained rivers; but their harmful effects can be felt. At best, we “merely” have to pay for the cost of replacing polluted water utility wells (it must be noted that more than 90 percent of public water consumption in Hungary comes from groundwater); at worst, human health can be threatened by the consumption of polluted water or garden-grown vegetables or even by recreation in polluted areas. Nevertheless, pollutants do get washed into surface waters, and decomposing hazardous wastes do threaten the environment through the air. This long-term environmental damage constitutes one of the factors of environmental pollution that has an unfavorable effect on public health and, ultimately, life expectancy.

With most long-term damage, the person (legal entity) that is responsible for the pollution cannot be compelled to clean up. In these cases, the coordinated use of government funds is necessary in order to clean up.

International Experience

It was only 10-15 years ago that the developed Western countries realized that polluted areas had to be gradually cleaned up. Germany (FRG), the Netherlands, Denmark, and the United States were among the first to react to the problem, while a high-level program is currently being implemented or, at least, planned in almost all of the EU member countries.

The task is enormous, even for the most affluent countries. This was not immediately evident. It was not unusual that the initial estimates for the cost of implementation later had to be increased tenfold. All of the countries are planning programs to be in effect for more than a decade. Even at the stage of planning, the development of soil and water protection strategies as well as the legal, technical, and economic regulations is necessary. The program organizers have faced numerous issues that have given rise to serious social debate. These issues include determining responsibility and, in connection with it, financing the work (which tasks are to be paid for by the persons that caused the damage and which are to be financed publicly?); the criteria for establishing intervention priorities; the rational objectives of interventions (the question is well-known: how clean is clean?); and the impact on property values.

It was usually recognized early in the course of planning the programs that the first step has to be a thorough study that will enable comparisons and uniform priority calculations. In the absence of such a study, the amounts to be spent on eliminating damage will not be efficiently used, and money might be wasted in some places, while other places might experience insufficient funding.

Initially, various theoretical criteria were applied in the stipulation of cleanup objectives and intervention limits. In the United States, an individual risk analysis is prepared for each examined area, and the specific tasks depend on the results of these. The Dutch practice faithfully followed the principle laid down in the European Soil Charter with regard to the soil's multifunctionality requirement. A state of cleanliness that is suitable for ecological and human activities must be achieved in all cases. In Germany and elsewhere, the list of limits was categorized according to area use requirements, adding that these limits are only starting points for individual evaluations.

In practice, most countries today tend toward using limits in the first phase of uncovering pollution and individual risk analyses in detailed investigations.

Although there are many methods of financing, government budgets dominate most of the time. The differences lie in the kinds of income schemes that provide coverage. These include product charges, waste taxes, and environmental protection contributions and fines, though on occasion there are no special sources and the public bears the full burden through the budget. The principle of "polluters pay," which is widely accepted in environmental protection, is least applicable here, since it is often impossible to prove the responsibility of the polluters.

Domestic Antecedents

The government's 1991 short- and medium-term action plan, which identified the tasks of surveying, uncovering, and terminating accumulated environmental pollution, can be considered as the starting point for the Remediation Program. The same plan deals with solutions to the environmental problems presented by abandoned Soviet barracks and training grounds.

Owing to the lack of funds, only the latter task could be started before 1995 under the technical direction of the Ministry for Environment and Regional Policy and the Environmental Management Institute. The remediation of the most polluted of the former Soviet properties will be completed in 1 to 2 years.

The experiences obtained in the course of privatization (many foreign investors were concerned about the risk of "inherited" environmental damage connected to properties), the revival of the real estate market, the experiences acquired as a result of the upsurge in bankruptcies and liquidation, and, hopefully, the developing public participation in environmental protection all helped provide justification for the Ministry for Environment and Regional Policy's original initiative. Therefore, the government launched the National Environmental Remediation Program in 1996 in order to assess polluted areas, uncover damage that falls within the scope of the government's responsibility, and eliminate the damage.

In September, Parliament approved the National Environmental Program, which contains the Remediation Program.

Government Responsibility

The new environmental protection law stipulates that if no other person can be made responsible, it is the task of the government to eliminate the consequences of significant environmental damage. Under certain conditions, the law stipulates the joint and several responsibility of the polluter and the owner of the area in which the activity causing the pollution is, or was, pursued. This provision will, in the long run, increase the chance of having the responsible persons, not the government, pay for eliminating environmental damage.

If, therefore, the polluter—

- is unknown (or if the presumed polluter cannot be proved to be responsible);

- has been terminated without a legal successor; or
- is currently under liquidation and the liquidated assets have been proved to be insufficient for cleaning up the damage—

the pollution must be considered a government responsibility and the damage on the given area must be eliminated within the framework of the Remediation Program. Naturally, it is also the responsibility of the government to clean up long-term environmental damage caused by government budget agencies.

The Purpose of the Program

The purpose of the Remediation Program is terminating the harmful and hazardous effect of long-term environmental pollution that falls within the scope of the government's responsibility. In order to achieve this, the first step that needs to be taken is the comprehensive survey of long-term environmental damage (sources of pollution and polluted areas).

The Course of the Program

The remediation concept extends over the entire process. As the first step of the Remediation Program, the environmental protection authorities started to survey the entire country in 1995 for pollution whose cleanup is particularly important. As a result, approximately 200 areas were registered. It is characteristic of the registered pollution that it endangers 86 percent of the soil and groundwater and a lesser degree of the air and surface waters.

The assessment of pollution sources and polluted areas requires extensive and very detailed work, which would make it possible to enter the results in computerized data bases. Version I of the Remediation Priority List can be compiled on the basis of the registered data with the help of a preliminary evaluation.

If it becomes apparent from the available data (without any further investigation) that rapid intervention is needed, there must be a emergency measure, which usually entails the localization of pollution or the elimination of the source of pollution. Fact-finding incorporates searching for the source of pollution, determining the damage to the polluted environmental component (soil, surface and subsurface waters, sediment, etc.), modeling the extent of the pollution, and preparing a feasibility study for the cleanup. The observation facilities that provide for continued monitoring are usually implemented by the time the fact-finding has ended. Fact-finding can be divided into two phases: a diagnostic phase, and a detailed probe phase. The risk evaluation for the given area is prepared on the basis of the results of the investigation, and the area is put on Version II of the Remediation Priority List in order to determine its priority.

In the course of remediating the polluted environmental elements, the pollution is terminated or, if complete cleanup is not possible or if the target condition determined by the risk calculations does not warrant it, reduced. The soil or water must be cleaned of pollutants, and the specified limit values must be met. If the intervention does not result in the complete elimination of pollution, the area will be put on Version III of the Remediation Priority List following another risk analysis and evaluation. The follow up ensures the continuous monitoring of the results of interventions. Follow up, which relies on the data provided by the observation facilities, can last for several years.

In the course of the program, if remediation would take several years, the environmental protection authorities will take measures to register the long-term environmental damage in the property register and, once the post-inspection is completed, have the entry removed.

Program Priorities

In the course of the remediation, the optimal solution must be realized in order to protect human health, as well as the flora and fauna. The requirements of environmental hygiene, therefore, are of primary importance in risk calculations, while, at the same time, cost efficiency requirements are also built into the evaluations.

Current and planned area use characteristics influence the degree to which soil is cleaned. Groundwater water resources that are located in the catchment area of mineral, medicinal, and drinking water bases enjoy priority, regardless of the type of water (shallow groundwater, karstic water, bank-filtered water, or deep groundwater). Intervention has a higher priority for water resources that are located in vulnerable geological environments. The basic requirement of the remediation process is to prevent the spread of the pollution from one environmental element to another.

Program Tasks

The program incorporates three distinct groups of activities. The general tasks include operating, managing, and coordinating the program. The recurrent tasks include compiling the annual priority lists and announcing tenders for companies that undertake to search out and clean up pollution (usually by means of the public procurement procedure in accordance with the size of the project). Strategic tasks include research and technical development that meets the program’s needs and the creation of a basis for developing legal, technical, and economic regulations. For public acceptance of the program, the development of a communication strategy and public relations, the organization of educational programs, and the editing and publishing of technical publications are indispensable. The development of a two-tier (central and regional) information technology system is considered a general task.

Sixteen percent of the program funds was used in 1996 for the performance of general tasks. The assessment of sources of pollution and polluted areas is the most important of the national tasks. This includes the registration of long-term pollution in the property register (in accordance with uniform nationwide procedures), the central operation of the monitoring system, and the development of groundwater monitoring and the Soil Protection Monitoring (TIM) system.

Another national task entails the development of so-called subprograms for remediation projects for which government organizations bear statutory (or contractual) obligations. Six percent of the program funds were used in 1996 for carrying out national tasks.

Individual tasks include the investigation of damage and remediation projects for which the government is responsible, as well as local monitoring, both according to schedules that comply with priorities.

Connection to Other Programs

In 1996, 78 percent of the program funds were used for performing individual tasks. The Wellfield Protection Program, adopted by the Government in 1995, is aimed at securing both operating and prospective wellfields that are located in vulnerable environments. In the course of this program’s diagnostic investigations, water catchment areas are identified with the use of models (the size of the area from which any possible pollution can reach the wells in a specific period of time is determined). In the protected zones of wellfields that have been specified in the above manner, potential pollution sources are assessed, and appropriate observation and monitoring zones are developed. The cost of developing and maintaining protected zones is paid for by the government in the case of prospective wellfield and, in other cases, by the license holder that uses the water. The alternatives to securing an area are worked out on the basis of an evaluation of the conditions, which follows the segregation of actual and potential pollution sources. Decisions concerning the measures that must be taken in order to secure an area (in addition to developing a monitoring system) are made in consideration of the cost/benefit analysis of each of the alternatives. This can also include eliminating the existing pollution in the ground or groundwater as well as eradicating the cause of the pollution.

The need for coordination between the Remediation Program and the Wellfield Protection Program can be clearly recognized with regard to assessment and registration as well as the actual cleanup. The people who are in charge of implementing the two programs act as liaisons in the area of exchanging information and making the actual decisions to clean up pollution.

There are also close ties with the National Environmental Health Action Plan (NEKAP), whose purpose is to survey and rank the most important environmental hygiene problems and study possible solutions at the national, regional, and local levels. The National Environmental Health Action Plan has also established a common database for the polluted areas, and it rates planned interventions.

The National Environmental Health Action Plan rates pollution by evaluating the environmental hygiene risks and considering local characteristics and possibilities. In some sample areas, highly detailed analyses (*e.g.,* environmental epidemiological investigations) are made in order to calculate risks. The findings of the National Environmental Health Action Plan provide a reasonably good basis for making comprehensive priority calculations, especially from the perspective of the Remediation Program.

Program Phases

The first two years of operation (1996 and 1997) can be considered the program's short-term phase. The development of the research, information technology, regulatory, and monitoring systems started in the period during which the program was established and its methodology created.

The government's responsibility and participation were clarified. The program's medium-term phase was compiled. The process of nationwide assessment began; and emergency measures, investigations, and cleanup projects were carried out with regard to individual tasks. The preparation of the related subprograms was in progress in 1997.

The program's medium-term phase (1998-2002) has five principal aspects:

1) The information technology background and research and technical development will continue to be emphasized in the course of carrying out the general tasks. These include, for example, compiling and publishing a list of the most suitable modern technologies for cleanup projects as well as developing methodologies for risk evaluation and cost/benefit calculations.

   Since the calculations that determine remediation priorities must be made in the various phases of preparation (on the basis of information of varying profundity), the calculation methods must be applicable in several versions.

   The compilation of the list of priorities for the current year, based on topical information, is a general task. The investigations and cleanup projects that are to be carried out (or begun) in the given year can be determined on the basis of this list.

   One of the important tasks of the medium-term phase is the development of the Remediation Program's funding system. This must take into consideration the fact that the fund requirement for the tasks planned for the medium-term phase exceeds HUF 20 billion as well as the fact that the cleanup of the environmental damage that has been generated over several decades will also last several decades following 2002 with a cost that will probably run into the hundred billions.

2) Important national tasks include a comprehensive assessment of the actual and potential sources of pollution that cause long-term environmental damage, as well as registration of the findings by developing an information system for inventoring polluted sites ("KÁRINFO"), which is integrated in the Environmental Information System. The most comprehensive version of the Remediation Priorities List was prepared on the basis of this for 2002. Of course, this cannot be considered the final list, since the continuous maintenance of data will have to be ensured even in the future, and long-term environmental damage can arise even in the meantime, although hopefully to a lower number.

   The national investigation entails a search for the sources of pollution that fall within the range of the government's responsibility, as well as those that do not. As part of this process, the existing data that can be used in the program are collected from various organizations (ministries, central or regional authorities, institutions, etc.) and processed. Useful data are available from previous inspections of pollution that endangers protected natural areas, studies of pollution sources that affect the Balaton catchment area and the region between the Danube and the Tisza, and the Groundwater Management Atlas. The processing of aerial and satellite photos can also be very helpful. Pollution in the soil or ground water is sometimes more noticeable on satellite photos of vegetation than in official files. Additional steps are the assessment procedure, including on-site data collection, supplementing and updating information, and searching for unknown pollution. The data obtained in the course of assessment are entered into the regional and national data bases in the KÁRINFO computer database management system, which will be available to the public in accordance with the legal regulations on public information.

3) The individual remediation tasks entail the investigation and cleanup of pollution for which the government is responsible in accordance with the schedule determined by the priorities. In the program's medium-term phase, which period is five years, diagnostic or partial investigations can be carried out in approximately 200 areas, if the program's finances are realized according to the plans.

   The need for rapid response will increase at first. Later, these interventions will be less characteristic. Accordingly, we can anticipate that emergency measure will be needed in approximately 50 cases.

   As opposed to this, the annual number of cleanups after fact-finding will gradually increase. It is possible to estimate approximately 50-80 remediation projects for the period leading up to 2002. In terms of the need for follow up, this means that approximately 1000 observation wells (or other similar facilities) will be established before 2002 as part of the monitoring system.

4) Most of the pollution that falls within the scope of the government's responsibility must be cleaned up within the framework of the subprograms. The individual subprograms are aimed at cleaning up government properties that are under the management of state holding companies. Hungarian State Railways Company's (MÁV Rt.) environmental pollution, for example, will be cleaned up and the damage left by state mining projects will be eliminated within the framework of such subprograms. Subprograms will be created to eliminate the environmental damage on military properties and other pollution in areas and properties held by other ministries or properties in the possession of budget institutions.

   According to the plans, State Privatization Agency (ÁPV Rt.) will be in charge of two specialized subprograms. ÁPV Rt.'s cleanup tasks are aimed not only at the existing government properties, but at the properties that ÁPV Rt. has already sold and on which it has assumed environmental protection guarantees on the basis of contracts of sale or the law. The government cleanup of former Soviet properties is carried out within the framework of one of the subprograms. The other subprogram is the so-called corporate privatization subprogram, which also incorporates environmental protection guarantees that were made mostly on the basis of individual decisions in the course of sales negotiations. The implementation of the corporate privatization subprogram contributes to the privatization of some companies for which investor interest has so far been dampened by the companies' previous environmental problems and, consequently, the high risk resulting from the accumulated pollution.

The persons in charge of directing the subprograms use the same investigation, registration, and risk evaluation methodologies that determine the order of priorities in individual interventions. The damage investigated in the various subprograms, therefore, can be compared to the individual cleanup requirements. The schedule, which is based on a comprehensive calculation of priorities, can be influenced to a certain extent by the characteristics of the given subprogram (*e.g.*, the manner in which military properties are used), its separate financial or budgetary position, or the deadlines for other tasks (in the case of ÁPV Rt.).

5) In the future, the government should not be held responsible for new long-term environmental damage, and the means of prevention must be created and developed in the program's medium-term phase. Prevention can be best served by the introduction of regulators, which have already been specified in the environmental protection law; these include environmental liability insurance and collateral requirements in proportion to anticipated environmental expenses. Although persons that pursue activities that pose a risk to the environment (*e.g.*, persons that handle hazardous wastes) or those that have undertaken long-term official obligations are further burdened by this regulation, corporate tax regulations provide incentives for putting the planned expenses into provisions. It is hoped that this regulation will create a situation in which, even if a company becomes financially unstable, allocated funds will be (at least partially) available for cleanup or for satisfying compensation claims and the cleanup will not have to be carried out from government funds allocated for the program.

   Another possible way of prevention is to carry out the cleanup for insolvent companies with advance official funds.

Based on this, a special finance regulation scheme can be developed. In simplified terms, the environmental protection obligation is replaced by the financial claim of the authority and therefore, as a result of flexible management and the possible participation of the Central Environmental Protection Fund, the company's liquidation due to the environmental debts of the previous years—or rather the previous decades—can be avoided, and the cleanup tasks that cannot be paid for with the liquidated assets will not burden the program. One possible example for the use of the scheme is the enforcement of Budapesti Vegyimuvek Rt.'s responsibility for the hazardous wastes it has stored in Garé, South Hungary. (Obviously, forcing the company into liquidation would not be an appropriate solution in either economic or environmental protection terms.)

Program Funding

In each of the program's first two years, the annual budget law allocated HUF 1 billion to the Central Environmental Protection Fund for implementation. ÁPV Rt. had to provide these monies from privatization revenue. Regular financing is necessary in the medium-term because of the termination of privatization revenues. The environmental protection law stipulates that the central budget and the government funds allocated for environmental protection must provide joint coverage for such expenditures.

According to preliminary concepts, the Central Environmental Protection Fund has the opportunity to collect its own funds if environmental load charges are introduced.

Management and Inspection

The Remediation Program is coordinated by the Ministry for Environment and Regional Policy with the participation of the ministries and professional and scientific organizations concerned. The program is operated by the Remediation Program Office, which was developed within the Environmental Management

Institution, with the participation of the environmental protection authorities. The office's activities are supervised by the assistant undersecretary of state for the Ministry for Environment and Regional Policy. A team of professionals assigned by the various departments of the ministry assist the assistant undersecretary of state in his duties.

The Ministry of Environment and Regional Policy makes regular reports to the Government concerning the program and the manner in which it is being implemented.

Specific Achievements in Individual Remediation Projects

In 1996, the Remediation Program Office announced open tenders for the diagnostic investigation of 15 areas and separate tenders for emergency measure in the case of eight of these areas. Nearly one hundred offers were received for the public procurement announcements.

The emergency measure were, with two exceptions, completed by the end of 1996, while the Remediation Program Office concluded contracts with the winners that bid for the diagnostic investigations at the beginning of 1997. Most of the investigations were completed by June 1997.

Most of the program's first (rapid) responses were aimed at neutralizing the pollution that were mainly left by companies which had been terminated or liquidated.

In summary, the Ministry for Environment and Regional Policy's remediation project was launched in 17 areas in the second half of 1997. Investigations will begin in nine of these areas, and emergency measure is necessary in four areas. With four exceptions, the remediation projects begun in the previous year are continuing with detailed investigation of the work, supplementary emergency measure, and/or cleanup.

THE NETHERLANDS

1. Legal and Administrative Issues*

According to the present estimates, the application of the multifunctionality approach to the estimated 110,000 seriously contaminated sites would have incurred costs of around US$50 billion. The Netherlands is now spending about US$0.5 billion per annum, which equals the sum that was initially thought to be sufficient to resolve the entire problem. But at this speed it would take about 100 years to end the operation.

In the meantime, soil contamination would hamper construction and redevelopment essential to economic and social development, and dispersal of contaminants in the groundwater keeps on making the problem even bigger. For this reason another policy is needed.

Recently, a document has passed parliament containing a new policy on soil remediation. The new approach abandons the strict requirement for contamination to be removed to the maximum extent, and instead permits cleanup on the basis of suitability for use. At the same time, the government proposed other changes to soil protection legislation, including greater devolution of responsibility for cleanup to local authorities and the creation of more stimulating instruments.

Basically the policy has switched from a sectoral to an integrated approach. This means that the market has to play a more prominent role and take more of the financial burden. Soil contamination should not only be treated as an environmental problem. The soil contamination policy should also be geared to other social activities such as spatial planning and social and economic development and vice versa.

The strategy is—

- to protect clean soil
- to optimize use of contaminated soil
- to improve the quality of contaminated soil where necessary
- to monitor soil quality

This new approach will be paired to stimulation of the development and application of new technology and to a more cost-effective organization of the actual clean-up. These measures taken together are expected to cut costs by 30-50 percent.

In this approach, remediation is part of a comprehensive policy regarding soil contamination. Prevention, landuse, treatment of excavated soil, reuse of excavated soil (for example, as building material), monitoring of soil quality and remediation have to be geared to each other in a more sophisticated manner. This "internal" integration is being promoted under the concept of "active" soil management.

To stimulate market investment, a different approach to government funding is announced. The taxpayers money will be used in such a way that it evokes private investment. This will be done by improving the existing financial instruments and by the creation of a private sector contaminated land fund. The legal instruments will be made more effective. The discretion of provinces and municipalities will be further enlarged to create the flexibility which is needed to initiate and stimulate the measures that are best suited to the local situation (tailor made solutions). In September 1997, Parliament accepted the new policy.

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*This text is based on *The Dutch experience; lesson learned*. Ton Holtkamp and Onno van Sandick, Ministry of Housing, Spatial Planning and Environment in the Netherlands, January 1998.

With these measures, the Dutch government wants to achieve ambitious goals:

- Within 25 years all sites should be made suitable for use and further dispersal stopped. That means that each year almost four times as much sites will have to be remediated as is the case now.
- Presuming that the costs will be reduced with 30-50 percent, this requires a duplication of the total annual expenditure on soil remediation.
- In order to monitor the results of these efforts and to make information on soil quality accessible to the general public (for example, potential buyers) and to authorities (for example, planning authorities), we want to have a system of soil quality maps covering the whole country in 2005.

2. Registration of Contaminated Sites

Based on the Soil Protection Act there are two driving forces to investigate soil quality:

- Anyone intending to excavate and to move soil for building activities has to report the quality of the soil to provincial authorities;
- Companies that do not investigate the soil quality voluntarily might be required to do so.

Based on these activities a lot of seriously contaminated sites have been identified. These numbers have increased enormously since the first case at Lekkerkerk.

Table 1. Inventory of sites

Year	Seriously Contaminated Sites	Estimated Costs (Billions US$)
1980	350	0.5 billion
1986	1,600	3 billion
1998	110,000	15-25 billion*

* based on new policy

3. Remedial Methods

In the policy on contaminated land, three phases are recognized. In the first phase, restoration was the aim of the technology. In the second phase, control of the spreading was added, and in the third phase control of risks has become the aim of technology.

Table 2 illustrates the development of technology in these phases. In the first phase the treatment technology for contaminated excavated soil has been developed. This was mainly the physio-chemical technology which was originally applied in mining and road building, such as particle classification (soil washing) and thermal treatment. In the next phase containment was added to these technologies. The main containment technologies are the isolation of a site by a non-permeable wall and pump-and-treat. In the latest phase the *in situ* technologies are developed, especially the *in situ* bioremediation.

Table 2: Development of Technology in the Netherlands

Period	Aim	Approach	Main technology
1983	Restoration	Excavation plus soil treatment	Physico-chemical
	No spreading	Containment	Civil engineering
1998	Control of risks	*In situ*	Biotechnology

Table 3 shows some results of the treatment of excavated soil in 1996. Approximately 1.7 million tonnes of soil have been treated, 60 percent by thermal treatment, 25 percent by soil washing and 15 percent by land farming. Thermal treatment is very effective; all the organic contaminants are destroyed.

Table 3. Proven technology in the Netherlands

Soil Processing in 1996: 1.7 x 10^6 tons			
Technique	**Mass**	**Contaminant**	**Effectiveness**
Thermal	60%	Organics	100%
Soil washing	25%	Organics/metals	80-95%
Landfarming	15%	Organics	60-90%

Table 4 shows the costs of the treatment of excavated soil exclusive of excavation and transport. The costs of treatment have rather decreased over the last five years. The average costs for treatment were about US$90 in 1991 and about US$50 in 1997. Cost reduction is a result of technological innovations and the market.

Table 4: Costs of soil treatment in 1997
(Source: Handbook Soil Treatment Technology, SCG The Netherlands)

Technique	Low US$ per ton	High US$ per ton
Thermal	30	85
Soil washing *	20	40
Landfarming	20	50

* Exclusive sludge disposal;
inclusive sludge disposal high: 65

Low: sandy / low moisture / non-halogenated contaminants
High: loamy / high moisture / halogenated contaminants

4. Research, Development, and Demonstration

In the Netherlands, the research and development of new strategies and technologies is organized in national research programs. The programs are fully or partially financed by ministries and partially by the private sector. The main ongoing research programs are:

PGBO—The Netherlands Integrated Soil research program is aimed at continuing and strengthening the Dutch knowledge infrastructure on contaminated land issues. The main activities are small projects on the starting and continuation of platforms for discussions, such as on risk management. Other projects are aimed at identifying needs for further research based on the experience in the field. The program has an average yearly budget of US$0.5 million. It will continue until the end of 1999.

NOBIS—One way to reduce the costs of soil remediation is the biological *in situ* approach. To strengthen the knowledge and experience in the Netherlands the NOBIS program started. The objective of NOBIS is to develop, evaluate and demonstrate innovative strategies, methods and techniques which will effectively help to control *in situ* remediation by means of biotechnology (biorestoration).

With a large scale application of the attained results a significant reduction in the costs of the soil clean-up operation will have to be achieved. A threatening stagnation in the solution of the soil clean-up problem can thus be counteracted. NOBIS will also help to improve the export position of the Netherlands in the field of knowledge-based soil clean-up products and services.

The program is supported by the Ministry of Economic Affairs with US$12.5 million and US$6 million has been supported by the private sector (mainly large industries). The program is running from 1994-1998.

There are about 40 ongoing projects. Some new approaches identified during the progress of the program are:

- Selection of remediation options based on risk reduction, environmental merit and costs (REC)
- Natural attenuation and biological active containment to control risks.

5. Conclusions

The Netherlands policy has been changed drastically in 1997. This has resulted in an increasing demand for knowledge on new approaches and new technologies. Therefore, the research effort will be continued and increased in the coming years.

NORWAY

1. Legal and Administrative Issues

The main law regulating clean up of contaminated land in Norway is the Pollution Control Act from 1981. The polluter pays principle forms an important basis of the Pollution Control Act. If the original polluter can no longer be identified or held responsible, the current land owner may be held liable for investigations and remedial actions.

Regulation of contaminated land in Norway under the Pollution Control Act is the responsibility of the Norwegian Pollution Control Authority (NPCA). While almost all sites are directly regulated by the national agency, only a few cases are left over to regional authorities (counties). The Planning and Building Act, however, requires that local authorities consider possible soil contamination before a new construction project or land development is licensed. During recent years national authorities have encouraged municipalities to use this law in their regulatory work and hence contribute to reduction of the number of construction projects which temporarily have to be stopped due to the discovery of soil contamination.

Contaminated land is generally accepted as a local environmental problem. Therefore the national and regional authorities are considering whether regulation of contaminated land should be the responsibility of the counties, alternatively how and to what extent counties should be involved.

Clean up of contaminated sites are at present regulated through permits/licenses under the Pollution Control Act. As the Norwegian procedures for licensing clean up and remedial actions are complicated and time consuming, the NPCA are preparing a “General Regulation for Contaminated Sites.” This allows private and public companies to conduct the clean up program for their sites without detailed permits or licenses from the authorities and saving time and cost consuming processes.

Norway has developed a decision model consisting of a two-tiered system for regulation of contaminated sites. Generic target values are developed for most sensitive land use. For other sites or when target values are exceeded, a system of site-specific risk assessment is applied. The target values are based on data from other countries.

Improving the target values and development of a systematic approach for risk assessment are issues of high priority in NPCA for 1997-98. This is a part of the decision model for contaminated sites in Norway which will be revised by the end of 1998.

Norway has decided not to apply the principle of “multifunctionality” as the basis for remediation. Because cleanup goals are adjusted to actual or potential land use, site-specific information regarding level of contamination, remedial measures, and land-use restrictions should be kept for future generations. Therefore, it is important that results from regulation of contaminated land are included in the land use planning system.

2. Registration of Contaminated Sites

Contaminated land in Norway is considered as an important source for contamination of rivers, lakes and fjords. More than 85 percent of Norwegian water supply is based on surface water, and consequently groundwater contamination has been of less concern in Norway compared to many other countries. Potential impact from industry, contaminated sediments and landfills on the marine environment is of greater concern. In some fjords recommendations of reduced intake of seafood is recommended, due to pollutants such as heavy metals, PCBs, PAHs or dioxins.

During the years from 1989 to 1991, a national survey of landfills and contaminated sites was carried out in Norway. Approximately 2,100 possibly contaminated sites were registered. The total number includes municipal and industrial landfills, industrial sites, gas works, military sites and sites from World War II. In 1992 the NPCA presented an action-plan for contaminated sites. A status and revised plan was presented with the national budget from the government in 1996. New contaminated sites have continuously been discovered through land development or construction activities.

In 1997 NPCA decided to produce an annual status report to the public with overview of contaminated sites and status of remediation. One annual report will satisfy the need for information in the public (media, NGOs, politicians, etc). The status for 1997 shows that more than 3,350 contaminated sites are now registered in Norway. About 150 of these are given high priority and additionally about 600 sites need to be investigated. Of these 750 sites, investigation has started on about 350 and in 250 sites remediation is going on or finished. The remaining 2,600 sites are given low priority with the recent land use. When redevelopment or construction work is planed for these sites necessary investigations and measures must be considered.

A GIS-database is developed by the NPCA to keep track of all registered sites and any investigation or remedial action carried out at the different sites. Information from the database will be used for reporting and by NPCA in general, by the counties and by municipalities for their planning purposes.

3. Remedial Methods

A recent market research on treatment technologies for contaminated land in Norway (November 1997) shows that following technologies are commercially available through Norwegian companies:

- Bioventing
- Vacuum Extraction
- Air Sparging
- Pump-and-Treat
- Biopiles
- Landfarming
- Soil Washing
- Solidification/Stabilization
- Incineration

In situ and *ex situ* bioremediation technologies are mainly conducted by contractors. In total, 5 to 10 consulting companies have experience with these technologies. In addition to the contractors about 3 to 5 companies have specialized in treatment of contaminated soil in Norway as their major activity. They have so far concentrated on solidification/stabilization, soil washing, land farming and partly incineration. Few sites are in the “remediation phase” so far, and easy access to and low prices on landfills are major reasons for the limited development and accessibility of treatment technologies on the market.

The NPCA has started projects on national and local scale to develop guidelines for management of excavated contaminated soil. The guidelines will be administrative tools for local, regional and national authorities and support the existing legislation on contaminated land. A more predictable assessment by the authorities is of great importance for society.

4. Research and Development

The Norwegian Research Council (NFR) decided in 1994 to establish a separate research program (GRUF) focusing on management of contaminated sites and landfills. The program goals are:

- to provide a better understanding of risks connected to contaminated sites;

- to develop and demonstrate cost-effective remedial actions for contaminated sites and landfills; and
- to develop effective methods of monitoring micropollutants from landfills and contaminated sites, including ecotoxicological methods.

Research and development projects initiated and/or funded by NPCA have concentrated on sampling and monitoring technology, heavy metals and treatment technology on PAH contaminated soil.

5. Conclusions

The Norwegian Pollution Control Authority give priority to following issues:

- Transfer of responsibility, competence and resources to county or regional authorities on the regulation of contaminated sites.

- Preparation of a “General Regulation for Contaminated Sites,” which allows private and public companies to conduct the clean up program for their sites without detailed permits or licenses from the authorities and saving time and cost consuming processes

- Development of an improved decision model for regulation of contaminated land including target values for sensitive land use and a systematic approach for site specific risk assessment.

- Annual status report to the public with overview of number of sites and status of remediation.

- Development of guidelines for management of excavated contaminated soil.

SLOVENIA

In recent months, a few changes have occurred in the field of environmental protection in Slovenia. The ministry responsible for the environment has decided to expand its activities from the strictly legislative to more practical areas, which means that it has begun to carry out certain activities in order finally to break the deadlock in environmental protection, although they are currently limited to certain areas only. In many other areas with acute problems, the state has still not decided whether to become practically involved, in spite of pressure from the public, the media and local communities.

Legislation which has come into effect in recent years includes the Law on Environmental Protection, adopted in June 1993, and the following implementational regulations based on the Law:

- Decree on the Tax for the Pollution of the Air with Carbon Dioxide Emissions (14 December 1996)
- Decree on the Border, Warning and Critical Imission Levels of Toxic Substances in Soil (14 December 1996)
- Decree on the Conditions and Procedures for Obtaining an Authorisation to Prepare Environmental Impact Assessments (7 December 1996)
- Decree on the Input of Toxic Substances and Plant Nutrients into the Soil (14 December 1996)
- Instructions on the Methodology of Preparing an Environmental Impact Assessment (7 December 1996)
- Regulation on the Types of Activity for which an Environmental Impact Assessment is Mandatory (1 January 1997)
- Decree on Noise in Natural and Living Environments (19 August 1995)
- Regulations on the Initial Measurement of Noise and Operational Noise Monitoring for Sources of Noise, and on the Conditions for their Execution (21 December 1996)
- Regulations on the Operational Monitoring of the Input of Toxic Substances and Plant Nutrients into the Soil (26 September 1997)
- Decree on the Water Pollution Tax (29 July 1997)
- Decree on the Form of the Tax Return Form for the Drainage of Technological Waste Water (15 March 1997)
- Decision Determining the Amount of Tax Per Unit of Water Pollution for 1997 (18 January 1997)
- Decree on the Emission of Substances and Heat in the Drainage of Waste Water from Pollution Sources (20 July 1996)
- Decree on the Emission of Substances in the Drainage of Waste Water from Facilities and Plants for the Production of Metal Products (20 July 1996)
- Decree on the Emission of Substances in the Drainage of Waste Water from Municipal Waste Water Treatment Plants (20 July 1996)
- Decree on the Emission of Substances in the Drainage of Waste Water from Plants and Facilities for the Production, Processing and Treatment of Textile Fibre (20 July 1996)
- Decree on the Emission of Substances in the Drainage of Waste Water from Facilities and Plants for the Production of Leather and Fur (20 July 1996)
- Regulations on Initial Measurements and the Operational Monitoring of Waste Water, and on the Conditions for their Execution (20 July 1996)
- Decree on the Emission of Substances into the Atmosphere from Lacquering Plants (10 December 1994)
- Decree on the Emission of Substances into the Atmosphere from Cement Production Plants (10 December 1994)
- Decree on the Border, Warning and Critical Imission Levels of Toxic Substances in the Atmosphere (10 December 1994)
- Decree on the Emission of Substances into the Atmosphere from Stationary Sources of Pollution (10 December 1994)

- Regulations on Initial Measurements and the Operational Monitoring of the Emission of Substances into the Atmosphere from Stationary Sources of Pollution and on the Conditions for their Implementation (21 December 1996)
- Decree on the Emission of Substances into the Atmosphere from Heating Plants (10 December 1994)
- Decree on the Emission of Substances into the Atmosphere from Waste Incinerators and During the Combined Incineration of Waste (10 December 1996)
- Decree on Concessions for the Commercial Exploitation of Water Sources in the Republic of Slovenia for the Supply of Drinking Water (25 November 1995)
- Decree on the Export, Import and Transit of Waste (10 August 1996)
- Decree on the Prohibition of Sale and Importation of Vehicles Without a Catalytic Converter (21 May 1994)
- Decree on the Quality of Liquid Fuels with Regard to Their Sulphur, Lead and Benzene Content (25 February 1995)
- Decree on the Management of Infectious Wastes which Appear in the Performance of Health Care Activities (7 October 1994)
- Decree on the Management of Wastes which Appear in the Performance of Health Care Activities (3 June 1995)

With these documents, the state has taken legal and, in certain cases, practical environmental protection measures.

In 1997, the environmental inspection body began operating in Slovenia; its duties include the monitoring and registering of all events and activities connected with environmental pollution.

All hazardous wastes in factories in the process of privatization have now been registered. This was done because wastes of this type have been lying around factory estates for years, and also in order to ensure that the new owners would provide for the proper processing of these wastes, as this activity will now be monitored by the inspection body. There are large amounts of these wastes: according to the data published in the media so far, at least 250 factories have considerable amounts of hazardous waste, which are mainly stored simply in yards or in improvised shelters. According to some sources, the actual amounts of these wastes far exceed those recorded by the inspectors. They can be found not only on factory estates but also on illegal dumps, and were often simply buried at different locations. Slovene experts estimate that there are about 30,000 tonnes or more of hazardous waste produced by industry in recent decades which cannot be processed or incinerated since Slovenia does not have the proper tools and technologies. In this area the state has done virtually nothing in recent years, although state institutions and the ministry responsible for the environment have in their possession data on the amounts of these wastes and also on their locations.

At present, Slovenia has no strategy of waste treatment at a state level. Public scandals and accidents, and the resulting hazards are becoming increasingly frequent, and the public is justified in its alarm. In recent months, the media has launched a virtual campaign against the responsible state institutions; the government only responds to actual incidents and to situations which create an exceptional public and media outcry. Slovene experts are aware that the problem needs to be tackled before Slovenia's accession to the European Union, in spite of the government's reluctance to contribute more finances from the state budget.

I outlined the problems related to overloaded dumps at the meeting in Golden, Colorado. Since the state is passing the initiative to the local communities in this area, by its failure to offer solutions at a state level, disputes arise between local communities, which wish to build dumps only for relatively small areas and the state, which prefers dumps for whole regions (several local communities). Larger dumps are cheaper to build and to manage in comparison with several small ones; the position of the state institutions is therefore understandable. However, since the state has not prepared a strategy at the state level which would include a regional division of the country and the compulsory construction of regional dumps for municipal and other waste, it is also not difficult to understand the position of the local communities, which wish to begin building new local dumps, since many present ones are overloaded.

The great collision between the state and its institutions on the one hand and the political leadership and local communities on the other was last seen in the dispute between the ministry responsible for the environment and the municipal authorities in Ljubljana. The city officials responsible for environmental policies and waste treatment decided that Ljubljana should buy its own incinerator for municipal waste, while senior state officials insisted that the strategy of waste treatment was the responsibility of state institutions (i.e. the ministry). They argued that local communities were subordinate to state strategy, in spite of the fact that the strategy of waste treatment at a state level had not even been prepared, let alone adopted in parliament. In all these disputes various lobbies encouraging or hindering certain solutions for their own financial interests have locked horns in battle. Without a court decision, the issue will probably not be resolved soon.

The monitoring of drinking water, which has been conducted for many years and in which many parameters are measured, has shown that the levels of certain parameters have significantly changed in recent years. Because of this, drinking water sources will have to be better protected in the coming years and the access of pollutants to the sources prevented. Slovenia had excellent drinking water for many years; only in a few cases did it have to be specially prepared or conditioned (disinfected, etc.), since the pollution of ground sources was minimal. In the last few years we have seen significant changes in this respect; ground water sources are increasingly polluted, and drinking water has to be prepared by various methods before it is introduced into the water supply system. The measurements of samples taken from ground sources and from water supply systems have shown it to be necessary (in addition to the parameters prescribed in Slovene legislation) in order to monitor certain other substances. These are primarily carcinogenic substances and pesticides. The latter are a consequence of the intensive use of these substances in agriculture.

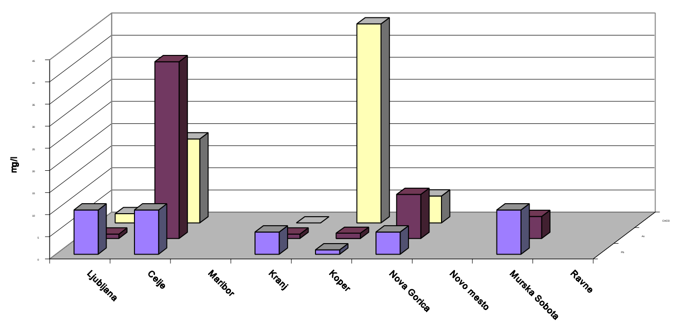

Figure 1

Analyses of drinking water conducted throughout Slovenia have yielded results within the expected limits. There have been no significant changes. However, in the last three years (1995, 1996 and 1997) we have begun to monitor the presence of certain other carcinogenic substances, such as arsenic, lead, trihalo-methanes, and last year (1997) certain pesticides as well, such as atrazine, alachlor, and their metabolites.

The content levels for As, Pb, and $CHCl_3$ for 1995 and 1996 are presented graphically (Figures 1, 2, 3). The presence of these carcinogenic substances in drinking water have never exceeded the legally permitted levels. For 1997 the levels of these substances are similar.

In 1997 we also began to measure the presence of atrazine and alachlor in drinking water (samples were taken from household water taps; see Figures 4, 5, and 6). Here the concentrations did not exceed the permitted values either.

Table 1 shows the highest recorded nitrate presence and the totals for pesticides in Slovene ground waters in 1996. From the pesticide totals it can be seen that the

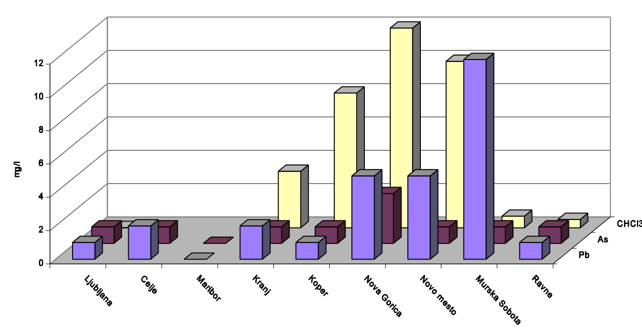

Figure 2

amounts of these substances in groundwater are highest in those areas with intensive farming, where large (indeed excessive) amounts of pesticides are still used.

Table 1. Nitrates and Pesticides in Groundwater [1]

Location	Nitrates mg/l	Atrazine μg/l	Metabolites of atrazine* μg/l	All pesticides μg/l
Prekmursko polje	131.1	0.85	1.90	1.55
Mursko polje	86.8	0.12	0.34	0.26
Apaško polje	46.9	0.27	0.96	1.24
Ptujsko polje	85.9	0.82	1.55	2.17
Dravsko polje	93.0	1.30	2.00	3.20
Dolina Hudinje	10.6	< 0.05	< 0.05	<0.1
Spodnja Savinjska dolina	98.3	0.18	0.63	0.73
Dolina Bolske	79.3	0.10	0.63	0.74
Vodiško polje	23.0	0.08	0.20	0.22
Kranjsko polje	24.8	0.13	0.19	0.31
Sorško polje	75.3	0.21	0.33	0.30
Dolina Kamniške Bistrice	37.2	0.47	2.39	1.69
Ljubljansko polje	28.3	0.32	0.32	0.45
Ljubljansko barje	10.6	< 0.05	< 0.05	< 0.1
Čatežko polje	21.0	0.05	0.05	< 0.1
Brežiško polje	25.2	0.23	0.52	< 0.1
Krško polje	63.1	0.24	0.81	0.48
Vipavsko Soška dolina	54.9	< 0.05	0.05	< 0.1

* desetilatrazine and desisopropylatrazine

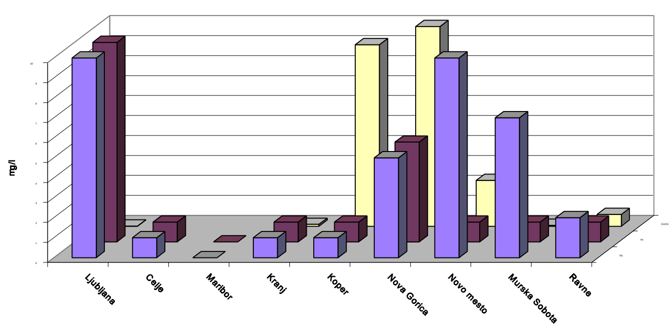

Figure 3

Examination and analysis of the above data indicate:

- excessive use of pesticides in agriculture
- the dumping of chemical waste at illegal dumps in the natural environment. In time, these chemical substances reach water sources.
- increased values of some of the substances may be attributed to various spillages of chemical substances due to accidents or negligence.

Accidents and spillages are statistically well recorded. The data is collected by the police and regularly published. Tables 2 and 3 show an annual statistical overview of spillages of various chemical substances in Slovenia.

Table 2. The number of incidents and the volume of leaked gases and liquids by year [1]

Year	1986	1987	1988	1990	1991	1992	1993	1994	1995
Number of accidents	85	54	48	124	86	89	94	97	93
Leaked in m^3	203	66	120	532	179	418	360	104	976
Chemicals in 10^3 l	85	66	34	81	96	126	29	35	26
Incidents involving amounts over 200 l	28	18	19	11	14	15	5	13	10

Note: There are no figures for 1989.

Table 3. Statistics on spilt substances in recent years (in litres of liquid) [1]

Liquid in litres – by year	1995	1994	1993	1990
Petroleum derivatives	22,500	32,980	23,950	72,710
Miscellaneous chemicals	3,413	2,215	4,990	9,250
Liquid gases	30,000	60	319,000	-
Other substances	726	30,000	-	-
Liquid manure	40,000	31,000	12,000	415,000
Miscellaneous waste waters	256	8,000	-	-

The results of these measurements and an overview of accidents and spillages indicate that the quality of Slovene drinking water is falling; laws and regulations are currently being prepared to limit the use of pesticides in farming and to protect ground water sources presently used as sources of drinking water.

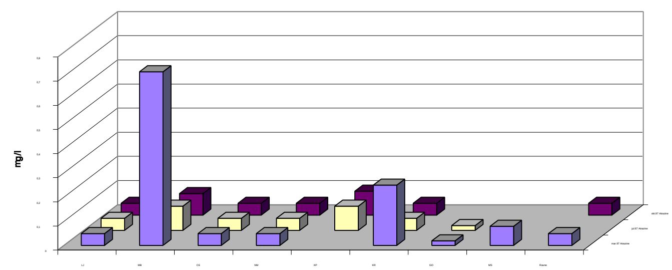

Figure 4

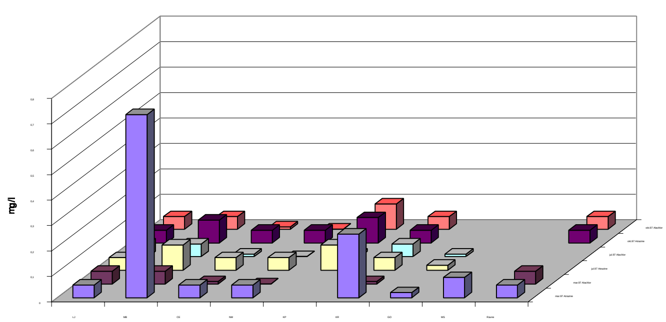

Figure 5

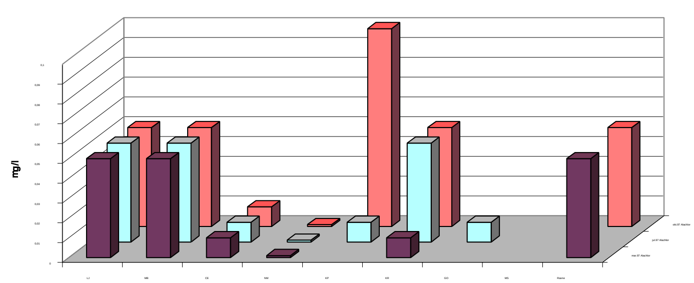

Figure 6

The next practical environmental measure undertaken by the state last year was a campaign to list all water polluters, including all factories, workshops and other places where activities producing industrial waste water are conducted. Monitoring is compulsory for all industrial waste waters, which includes the qualitative and quantitative analyses of contaminants. The legislation stipulates that the measurements must be conducted up to six times a year for certain pollutants, depending on the quantity of waste water. The measurements are conducted by authorised institutions which were awarded concessions for carrying out this monitoring. On the basis of the results of chemical analyses, the polluters must pay appropriate financial compensation to the state. The institution holding the concession to monitor industrial waste waters must communicate the results of the measurements and analyses of waste waters released by individual polluters to the authorised state institution, such as the Ministry of the Environment and Physical Planning, which on the basis on the analyses, quantities and types of burden placed by waste water on natural waters calculates the amount of tax to be paid by the polluter. The level of this tax depends on the quantity of the industrial waste water and the presence of contaminants. The regulations strictly determine the amounts and types of contaminant in industrial waste water which are permissible and which do not endanger natural waters, as well as the amounts and types of contaminant placing a burden on natural waters and sewerage systems, and related compensation for each individual contaminant and amount. The money thus collected is earmarked for the construction of purification plants for those industrial systems which are not financially able to build their own purification plants, priority being given to those polluters whose waste waters are most contaminated. The taxes for industrial waste waters have been increasing every year and many polluters now wish to build their own purification plants at factory sites, raising state loans provided by the Environmental and Development Fund. This is a special fund ensuring that state money intended for environmental issues is indeed spent for this purpose. The loans from the fund are intended exclusively for the construction and purchase of devices and technologies which contribute significantly to solving environmental problems.

The monitoring of industrial waste waters has been conducted for one year, since the beginning of 1997. High fines are prescribed for the violators and for those who do not arrange measurements with the authorised institutions. The measurements have already yielded some results, particularly in changing the attitude of polluters towards their waste waters. Corrective measures which are being introduced in certain factories and the construction of water purification plants are the most significant steps in this field.

In addition to the above problems and certain activities which are already underway in order to solve or at least mitigate them, a number of other burning environmental issues exist in Slovenia today which will have to be tackled in the coming years. The most pressing problems are probably that of waste treatment strategy, both municipal and industrial, the protection of soil, rivers, lakes and the sea, and the protection of the atmosphere in certain areas.

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2. B. Družina, P. Otorepec, A Preliminary Proposal for the Preparation of Scientific Foundations for the Introduction of the Monitoring of Contaminants Affecting the Health of Humans, Health Protection Institute of the Republic of Slovenia, Ljubljana, January 1996.

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SWEDEN

1. Legal and Administrative Issues

Sweden is still suffering from a lack of legislative support. There is no special legislation covering remediation-related issues yet. We have the Environmental Protection Act from 1996 which was not drafted to take in account remediation problems. The legislation is both unclear and incomplete concerning remediation.

Due to the recently announced ruling of the Supreme Administrative Court, the possibilities of placing demands on companies that have closed down have been limited to the period after 1989. This means that about 75 percent of the remedial cost must be covered by society.

The need for new legislation has been obvious for some time and in 1996 the Swedish EPA submitted a proposal for new legislation on remediation to the Government. This legislation has been incorporated in the new Environmental Code, which is currently under consideration and will come into effect on 1 January 1999.

The purpose of this new legislation is to clarify liability and give the authorities greater opportunity to promote, control and steer remedial action. With this new Code, it will be possible to place demands on companies from 1969 onwards. This new legislation also introduces the official registration on confirmed contaminated sites.

In 1997 the Swedish EPA presented guideline values for 36 contaminants in contaminated soil. Guidelines for the remediation of gas stations, including guideline values for soil and groundwater, are under consideration.

The Swedish definition of a contaminated site is a site, deposit, land, groundwater or sediment which has been contaminated, intentionally or unintentionally caused by industry or some other activity. The definition of “contaminated” is that the levels of contamination apparently exceed the local/regional background values.

The new Environmental Code will give the authorities quite a different role in the remedial work. It will make it possible to take a more active role and enforce private companies to take greater responsibility for their actions than they do at present.

2. Registration of Contaminated Sites

So far we have identified about 3,000 potential sites in Sweden. We estimate the total number of contaminated sites to be 10,000 sites. Due to our industrial structure, sites with metallic contaminants dominated mines with acid mine drainage are our heaviest and most costly remedial problem. Other problems are caused by metal works, iron and steel works and surface plating facilities.

Secondly, there is a group of industries with complex mixtures of metals and persistent organic substances such as chloralkali (mercury and dioxins/furans); these include gasworks, pulp and paper industry (mercury and PCB) and wood preservation plants (CCA, Cu, PAHs, PCP, and dioxins/furans).

Thirdly, we have the petroleum industry with oil refineries, oil depots and gas stations which represent the largest group by number but also cause problems which are easiest to solve.

Today we have an informal registration of identified, suspected sites at the Swedish EPA. This register is not official and only open for the environmental authorities. A more developed and regionally based computer system at the County Administrative Boards (CABs) will replace this first database in one to two years. The Swedish EPA is responsible for the development of this regionally based site registration data system in order to ensure that the regional registers are consistent. The purpose of this database is that it should provide a basis for the regional planning and the prioritization of inventories, investigations and remedial work, as well as serve as a support in the ongoing work on licensing and supervision.

With the new Environmental Code, the CABs will be authorized to decide which sites can, with certainty, be classified as contaminated in an official register. General criteria for this registration will be regulated by law. This registration can, in certain cases, lead to land use restrictions, obligation to report certain kinds of activities (like excavation) at the site to the municipality, etc. This information will also be entered into the national land register. The CABs will also be given the right to decide if and when such a classification should be annulled.

3. Remedial Methods

The EPA's policy in the context of remediation is to choose long term solutions that, if possible, solve the problem once and for all. That means in the first instance, to select methods which destroy the contaminant through biodegradation or combustion. When this is not possible, as in the case of metals for example, methods should be used where the contaminant is concentrated/collected for further treatment and/or landfilling. By concentration methods we mean, for example, soil-washing, soil-venting, and thermal desorption. Only in the last instance should methods such as containment, immobilization and landfilling of untreated residues be selected. This is an application of the BAT(Best Available Technology) principle in the remedial field.

The second principle that concerns the choice of technology is the eco-cycle principle. Site remediation has to do with the rational management of land and water resources. Methods which enable land and soil to be re-used are given higher priority than methods which involve the excavation and removal of waste as well as landfilling.

Landfilling, encapsulation and incineration are still the dominant remediation measures in Sweden. During 1997 two rather large sites, both of which were former wood preservation plants, have been successfully remediated using soil-washing. The trend is that some kind of treatment is becoming more and more common. In particular, biological methods like composting and *in situ* methods, such as vapor extraction and bioventing, are becoming more and more frequent.

The state of the art in Sweden is as follows:

Soil-washing. We have three pilot plants and two full-scale plants in Sweden. In addition, there are three more full-scale plants planned.

Thermal desorption. Two pilot plants have been tested and one full-scale is under construction.

Composting. We have a great number of companies dealing with uncontrolled composting, in open air without evaporation or leaching control. In controlled composting, we have two companies working with some kind of on-site static, encapsulated compost.

In situ methods such as soil vapor extraction, bioventing, and air sparging are used by one company, mostly for remediating gas stations.

Finally, we have a company developing a pilot bio slurry reactor into a full-scale plant.

The problem in Sweden is that there are still only a small number of remediations carried out. Despite the fact that there are quite a lot of companies interested in working in this field, the market is still very small.

One bright spot is the initiative from the Swedish Petrol Institute to get the petroleum companies to form an environmental commission to clean up petrol stations which have closed down. The work will be financed by a marginal increase in petrol prices. The aim is that 6.000 petrol stations will be remediated within a 10-year period. This will surely increase the demands for remedial work and make the market larger, at least for biological methods and in-situ methods such as vapor extraction and bioventing.

Another positive development is the Government's investment in building a new ecological society. Together with housing, energy and transportation, remedial action is one of the sectors where money will be spent. US$700 million will be spent under 3 years. Local authorities will present plans to the government, who will prioritize and allocate the funds. The Swedish EPA is not much involved in these decisions and our funds for the long term plans have been cut down to a minimum. This is a general trend in Sweden. The environmental authorities get less and less money and temporary organizations, often run by politicians, are formed to administrate regular authority work on an ad hoc basis.

Based on rather few remediations, the conclusion is that biological treatment, such as composting, should be used if you have an easily degradable organic contamination as at petrol stations, oil depots and refineries. *In situ* methods such as vapor extraction, bioventing and air sparging are also useful in some of these cases. These methods are rather cheap.

Composting could be used for lighter PAH but if you have 4-6 ringed PAHs or PCP, a bioslurry reactor is needed.

As we have a lot of sites with mixed contaminants, metals and organics, soil washing is a very useful technology in Sweden. The two full-scale remedies last year worked out very well.

Concerning thermal treatment, we do not have any experience of full-scale treatment yet, but the tests shows that it could be useful for PAHs, mercury, dioxins, etc.

4. Conclusions

Metals and complex mixtures of metals and persistent organics are the dominating problem in Sweden. Acid mine drainage is our major, and most costly, remedial problem.

The lack of technology has been a great problem but in the last few years we have seen a change for the better. The interest from treatment companies has increased and today there are around 15 companies active on the market. Some of these are developing their technology from the beginning, others are seeking collaboration with companies from other countries, such as the Netherlands or Germany.

The lack of legislative support and of Governmental long-term funding make the market unsure. The financial sector's increasing awareness makes it more and more difficult to hide these problems, giving companies the incentive to clean up voluntarily. The new Environmental Code and the remedial programs for gas stations will hopefully help the market to survive until the remedial program can get more stable financing.

SWITZERLAND

1. Legal and Administrative Issues

The population of Switzerland is about 7 million, living in an area of 41,000 km^2. Outside the sparsely populated mountainous region, which comprises about 60 percent of the country's surface, most people live or work in the urban areas of the lowland. The country's political structure is federalist, organised and divided into 23 states, called Cantons. These Cantons are very different in terms of surface area and population, as well as economy, industrialisation and scientific background. Industrial waste, waste management and environmental impacts also vary considerably.

The first steps towards a systematic assessment and remediation of contaminated sites were made by local authorities in 1985. Today about 75 percent of the estimated 50,000 suspected sites are registered by the Cantons and the Federal Department of Defence. The Cantons are responsible for entering the sites contaminated with waste in a register, differentiating among landfill, industrial and accident sites. The registration of industrial sites, which is carried out according to the branch of industry concerned, is difficult. Sites should not be put on the register if they are not polluted with waste.

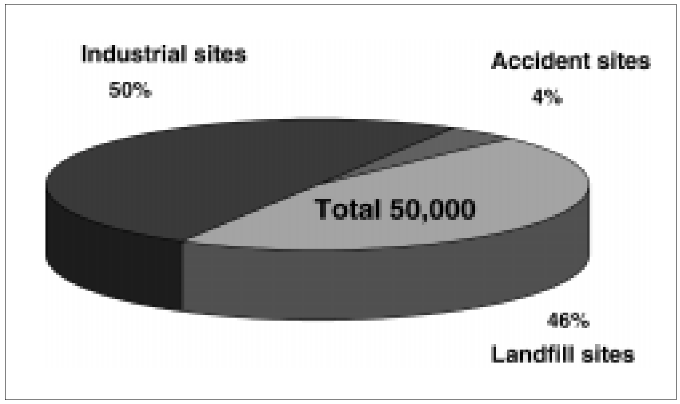

Figure 1. Estimated number of polluted sites in Switzerland.

In total we can reckon on more than 3,000 contaminated sites that will have to be remediated in the next 20 to 25 years. Up to 200 contaminated sites have been remediated to date. According to current experience 5-10 percent of the polluted sites (about 3,000) need to be remediated (Figure 2).

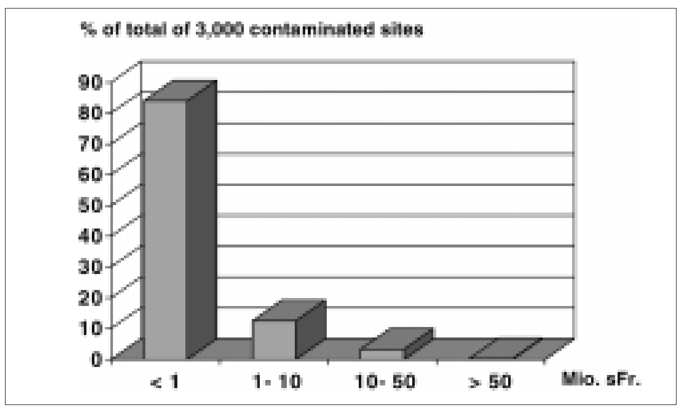

Figure 2. Estimated distribution of the cost of remediating contaminated sites in Switzerland.

The overall remediation costs for these contaminated sites are estimated by the Federal Agency at over 3 billion ECU (5 billion Swiss Francs).

It can be assumed that more than 80 percent of the sites (about 2,500) will generate costs of less than 1 million Swiss Francs.

2. Legal Framework for the Management of Contaminated Sites in Switzerland

Regulations for management of contaminated sites were established in the 1995 revised Law relating to the Protection of the Environment. This amendment, to the Law of 1983 relating to the Protection of the Environment, regulates the management of contaminated sites for the first time in Swiss environmental legislation, in the following three articles:

- **Registration and remediation**: Obligation to register landfills and other sites polluted by waste (contaminated sites) in a register open to the public; obligation to remediate polluted sites, if they result in harmful effects or cause a nuisance to the environment or if there is a danger that such effects may arise (contaminated sites).

- **Regulation of financing**: “Polluter pays” principle; the owner of a site is excepted if he or she could not have had any knowledge of the contamination, did not stand to gain from the contamination, or will not stand to gain from the remediation. The authorities rule on the division of the costs if people with an obligation to remediate so require.

- **Levy to fund remediation**: Levy on landfills of up to 20 percent of the average costs in order to finance remediation projects, where the polluter cannot be identified or cannot pay, or where domestic waste is to be remediated.

Based on the revised Law relating to the protection of the environment the Ministry of Environment, Traffic, Energy and Communication plans to put into force the Ordinance relating to the remediation of contaminated sites by 1 July 1998. This ordinance has the following objectives:

- **Stop emissions at source:** the remediation criteria are not based on the pollution itself, but on the emissions from it that lead to unacceptable immissions in waters, air or soil; decontamination, containment and use-restrictions for the soil are all therefore acceptable as remediation measures;

- **Cooperation between polluters and authorities:** authorities and polluters may carry on working as long as possible under agreements, instead of the need for a ruling; agreements among branches of industry should be encouraged;

- **Legal equality** through harmonised criteria (*e.g.*, 72 intervention values, remediation targets, leaching tests) and uniform requirements for the elaboration and management of registers, planning and execution of investigations, as well as monitoring and remediation projects;

- **Prevention against new risks:** building activities on polluted sites are permitted only if it can be proved that the site does not need remediation, if the project does not hinder future remediation, or if it will be remediated in the course of the project; containment measures have to be effective long-term, controllable, reparable and financially guaranteed.

Priority setting and stepwise management:

- Registration and prioritisation: The register of polluted sites is open to the public and must be completed by the Cantons by the year 2003. The registered sites should be prioritised and the register updated continuously. Sites which are completely decontaminated will be deleted from the register;

- **Remediation decision:** On the basis of a historical and/or technical investigation it will be decided whether the site needs no further action, monitoring is necessary, or remedial action is required;

- **Remediation objectives and urgency:** The general objectives of remediation are to remove the need for remediation; on the basis of the results of the risk assessment the Cantons may deviate from these general objectives under certain circumstances (according to use, ecological and economic commensurability, environmental merit); sites which present an acute danger must be treated immediately, for others the date by which a remediation project is to be completed must be set by the Cantons according to the risk assessment;

- **Remediation:** The polluter is obliged to devise a remediation project which includes remediation and monitoring measures (including waste disposal, long-term feasibility, time needed to reach the objectives), an eco audit of the measures to be taken, preventive measures for the case that the remediation undertaken fails, cost-effectiveness, distribution of costs, etc.

In the revised Law relating to the Protection of the Environment (LPE) the section on remediation of contaminated sites and the financing thereof has its own regulations due to its importance. Art. 32e of the LPE gives the Federal Council the authority to introduce a tax to finance remediations. The tax should be levied on the deposition of wastes; the rate is limited to a maximum of 20 percent of average deposition costs in Switzerland. The revenue is expressly related to this purpose and flows to the Cantons (if they fulfil certain conditions), which must in turn find the finance to remediate contaminated sites. The amount of the compensation is limited to 40 percent of the countable remediation costs; at least 60 percent of the remediation costs must be borne by the Cantons.

The issuing of Federal regulations to cover financial cooperation in the remediation of contaminated sites is justified because for many sites the polluter is no longer identifiable, or is unable to pay. In these cases the costs of remediation, insofar as they cannot be passed on to the proprietor, will be carried by the Cantons and thus by public taxes. This planned ordinance will enable the Cantons to receive financial support from the Confederation.

Furthermore, this fiscal instrument should offer an incentive for the quick and environmentally sound remediation of contaminated sites. It is the Confederation’s aim that contaminated sites, which represent a severe potential danger, should not only be investigated but also be rapidly remediated. Remediations should be provoked by the actual danger to the environment, and not just by development, building plans or the presence of adequate sources of money.

3. Remedial methods

In the approximately 200 remediations carried out to date, “classical” methods of remediation were predominantly used. These are primarily:

- Excavation of the contaminated material and treatment in a soil-washing facility or disposal in a landfill
- Securing of the site (*e.g.*, sealing of surfaces, barrier walls).

New and innovative remediation technology, particularly *in situ* measures, are still not completely accepted. Efforts are especially necessary in this area, to which the authorities can contribute.

When the Ordinance on contaminated sites comes into force, it will be possible to keep a register of remediations carried out in Switzerland and keep more comprehensive information on individual cases than is currently possible.

4. Research, Development and Demonstration (RD&D)

Switzerland, in contrast to other countries, does not have the financial means to promote large projects to research or develop innovative remediation technologies. Furthermore, there is no program of technology promotion in existence. The limited means available are primarily used for urgent, practical tasks such as:

- Decision tools for risk assessment
- Applicability of ecotoxicological methods
- Guidelines for taking samples

SAEFL particularly supports practical projects in the area of biological and “intrinsic” remediations as well as the containment of contaminated sites (*e.g.*, reactive wall systems, barrier walls).

5. Conclusions

Current Federal policy on the treatment of contaminated sites is oriented primarily according to the following important principles:

- Uniform goals for the treatment of contaminated sites should be valid throughout Switzerland.
- The authorities work with those directly affected, especially with industry.
- The contaminated sites should be treated according to objective urgency (danger to the environment).
- Remediations should be carried out quickly with realistic solutions (principle of commensurability); the search for perfect solutions, and thus leaving the problem for future generations, should be avoided.
- The requirements of remediation should be set, as far as possible, according to the environmental situation at the time.
- The remediation should guarantee that illegal effects are permanently halted and that the measures are sustainable overall.
- Contaminated sites are to be decontaminated where possible and to be secured as a secondary priority.
- Future contaminated sites should be avoided through consistent implementation of precautionary environmental regulations.
- Industrial and commercial contaminated sites are to be remediated as far as possible for future use. “Brownfields,” and their subsequent replacement with “greenfields,” are to be avoided.

The legislator has the difficult task of issuing regulations with which environmentally legitimate treatment of contaminated sites is possible and on the other hand ensuring that these regulations are acceptable to the population and those affected by a remediation.

The registration of sites contaminated with waste is valuable. On the other hand there is still great necessity to investigate the sites and their possible remediations, which could in some cases be very cost-intensive. Prerequisites must be created so that investigation and, if necessary, remediation can be carried out, not just where there are plans for construction, but also where it is necessary for purely environmental reasons. We hope that the planned ordinance on the financing of the remediation of contaminated sites will offer a significant support to this.

TURKEY

1. Legal and Administrative Issues

There is growing recognition of soil and groundwater pollution problems in Turkey since the enforcement of the regulation of the *Control of Hazardous Wastes* in August 1995. The main purpose of the regulation is to provide a legal framework for the management of hazardous wastes throughout the nation. It basically regulates prevention of direct or indirect release of hazardous wastes that can be harmful to human health and the environment, control of production, transportation and exports, technical and administrative standards for construction and operation of disposal sites, waste recycle, treatment, minimization at the source, and related legal and punitive responsibilities. The regulation is applicable not only to hazardous wastes to be generated in the future, but also concerns with the existing hazardous wastes and their safe disposal in compliance with the current regulation within three years.

The *Control of Hazardous Wastes* regulation does not explicitly define the concept of contaminated sites. Rather, it defines what a hazardous waste is and provides lists categorizing hazardous wastes based on their sources, chemical compositions and accepted disposal techniques. Thus, any site contaminated with or subjected to any of these categorized hazardous wastes can implicitly be defined as a contaminated site. However, difficulties arises from the lack of information for most of chemicals in these lists regarding specific maximum concentration levels (MCLs) or remedial action levels.

Currently, identification of any contaminated site is not based on a certain systematic approach. These sites are mostly identified after some potential environmental problems become obvious and public as a result of the efforts of local authorities or concerned citizens. However, some current policy developments by the Ministry of Environment can make the identification of contaminated sites somewhat more systematic. In this new policy development, the waste management commission, an administrative body proposed by the *Control of Hazardous Wastes* regulation, initiates preparation of industrial waste inventory on a regional basis. Waste inventory is planned to be achieved by requiring all the industry to fill out *annual waste declaration forms* revealing the type, amount, composition and the current disposal practice of their wastes. This way, it is expected that waste generation activities and pollution potentials of industries can be monitored; regionally effective waste reutilization and recycling programs can be implemented; and finally regional needs for the type and capacity of waste disposal facilities can be identified. In response to such efforts, an integrated waste management facility, including a landfill and incineration unit for disposal of industrial wastes, is becoming operational at full scale in heavily industrialized Izmit region.

Another policy development related to identification of contaminated sites is the work progressing towards the preparation of a "*Soil Pollution Control*" regulation. It is expected that this regulation will clarify the existing confusion over the remedial action and cleanup levels and set a guideline for the selection of appropriate cleanup technologies for various different types of contaminated soil sites.

2. Contaminated Sites

Same examples of the identified contaminated sites and major soil and groundwater problems associated with these sites in Turkey are as follows:

- **Beykan Oil Field Site**: At this site, petroleum hydrocarbon pollution of surface soils, surface and groundwater caused by oil production activities in the Beykan Oil Field is of concern. The Beykan Oil Field is enclosed by the watershed of a medium size dam constructed during early-sixties for irrigation purposes. Due to recent increases in domestic water supply demand, the dam was considered as a potential resource to meet the increasing water demand in the area. A total of 38 oil producing wells are placed within the various protection zones surrounding the dam's reservoir; 13 of them being in the immediate vicinity, within the first 300 m of the reservoir shore called the "*absolute protection zone.*" Oil spills at these wells and along pipelines connecting wells and other facilities are considered as potential pollution sources effecting the reservoir water quality. Existing spill records revealed that, during the peak oil production years, an annual average spill volume of 95 tons for the entire field, resulting in an average TPH concentration of 20,300 ppm in contaminated soils. As a consequence, contaminant mass leaching to the reservoir from soils contaminated by oil spills is viewed as a primary concern for reservoir water quality. In addition to soil and possible reservoir water pollution problems, another primary concern at this site is pollution of the Midyat aquifer due to injection of nearly 20 million m^3 of formation water between the years of 1971 and 1996. Injected formation water contains high amounts of brine (with a chloride concentration of 3,000 mg/L and TDS concentration of 6,500 mg/L) and some emulsified oil (with a concentration of 500 mg/L). The Midyat aquifer overlies the Beykan Oil Field and a primary source of drinking water supply for the nearby community. For this site, studies concerning the assessment of the extent of contamination and appropriate remedial measures are currently underway.

- **Incirlik PCB Contaminated Soils Site**: At this site, soil contamination by PCB oil leaking from storage drums at a military reutilization yard was occurred during the operation of the reutilization yard between the years of 1970 and 1988. An excavation of 0.5 meters deep was made in October 1991, leaving the excavated soil stored in approximately 300 drums and in a pile. Estimated PCB-contaminated soil volume is 1,600 m^3. Site characterization investigations revealed that site soils are high in clay content (65 percent) and potential for groundwater contamination is low. PCB concentrations measured in composite contaminated soil samples range up to 750 ppm. For remediation of contaminated soils, various alternatives are being evaluated including incineration and *in situ*/*ex situ* solidification/ stabilization (S/S).

- **Chromium Ore Processing Residue Dump Site**: At this site, soil and groundwater contamination by Cr(VI) leaching from chromium ore processing residue (COPR) is of concern. COPR is produced by a chromate production factory providing mostly the needs of leather tanning industry. During the early production years, COPR is dumped at a temporary dump site near factory. The unprocessed row chromite ore ($FeCr_2O_4$) contains nearly 45 percent of chromium oxide (Cr_2O_3). After a roasting process of chromite ore by adding Na_2CO_3 and $CaCO_3$ constituents, COPR contains nearly 25,000 ppm of total chromium. Due to high chromium content, COPR is partly recycled by mixing with chromium ore at a ratio of roughly 1:20. The current chromate production technology used yields approximately three (3) tons of COPR to produce one (1) ton of chromate. Currently, some research work is underway to evaluate soil and groundwater pollution potential of land-disposed COPR and to develop technical guidelines for appropriate management of COPR related wastes and remediation of COPR contaminated soils.

Ystambul Solid Waste Projects

The former uncontrolled dumping site at Yakacýk (on the Asian side of Ýstanbul) bearing 600,000 cubic meters of unclassified refuse over an area of 80,000 square meters has been banned to refuse dumping since 1990, and rehabilitated since 1995 to solve the environmental problems of about 10,000 settlements. The outlines of the rehabilitation project consisted of:

- gas collection plant capable of incinerating 1,000 cubic meters of stored gas at a power of 500 kW (burning temperature is 1,200°C)
- 500 m stream amelioration
- sporting and recreational fields with cycling grounds
- 80,000 m^2 of recovered green fields

The project cost was US$1.6 million. In addition to serving basic environmental problems of surrounding settlements, the project also eliminated the extremely dangerous (explosion risk) methane gas which reached the basements and ground floors of nearby houses.

The daily refuse collection of Ýstanbul amounts to 9,000 cubic tons (6,000 cubic tons from the European and 3,000 from the Asian side) are compressed to a small volume at six transfer stations, and carried to ultimate disposal sites by 76 trucks. About 25 percent (2,250 cubic tons) of total collected refuse consists of recoverable wastes like glass, paper, metal and plastics. The solid waste project of Ýstanbul Metropolitan Municipality envisages efficient classification of refuse bringing about 50 percent energy saving with 15 times reduced water pollution (to surrounding water bodies). The infectious sanitary wastes are separately collected and incinerated at 1,100°C.

The current status of the former uncontrolled dumping sites of Ýstanbul already rehabilitated or under amelioration work is as follows:

- Ümraniye (Asian side) is rehabilitated to green fields and sporting grounds.
- Halkalý (European side) is banned to dumping; the programmed rehabilitation work will be completed by 1998, reducing the environmental hazard of the site to nearby settlements.
- Kemerburgaz (European side) has completed the construction of the linking roads, and is scheduled to be rehabilitated by the end of 1998. A composting plant occupying 35 hectars of land with an organic refuse intake capacity of 1,000 cubic tons per day has been adjudicated, and is programed to operate by the end of 1998. The plant will give service on 24-hr basis producing 350-400 cubic tons of compost fertilizer per day. Electrical energy production from the evolving methane gas is thought to meet the local power consumption.
- Yakacýk (Asian side) is banned to dumping; it is basically rehabilitated since 1995, and gas collection and incineration plant is in operation.
- Aydýnlý is banned to dumping; rehabilitation project adjudicated in 1997.

Solid Waste Disposal Project goals in 1997 include:

- Biogas (CH_4) Production: US$11 million (covering energy production from solid waste storage gas and energy transport)
- Wastewater Treatment Plant of Leakage Water from Solid Waste Processing (for plant construction): US$3.4 million
- Rehabilitation of Kemerburgaz Solid Waste and Refuse Disposal Site: US$4.2 million
- Rehabilitation of Aydýnlý Site: US$2.2 million
- Rehabilitation of Halkalý Site: US$9.7 million
- Odayeri Treatment Plant: US$0.8 million
- Kömürcüoda Treatment Plant: US$1.7 million

Incineration of Infectious Wastes

The capacity of sanitary wastes collected from all hospitals of Ýstanbul is about 25 ton/day (105 hospitals). Although Ýstanbul Metropolitan Municipality supports the segregation of infectious wastes, a number of hospitals are not ready for such a classification in terms of their internal organisation. Assuming full capacity, the incineration plant is thought to produce 450 kVA (kilo-voltampere) of electrical energy.

Rehabilitation of Ýstanbul's Golden Horn Estuary and Dredging of Heavily Contaminated Benthic Sludge

By the completion of construction of Northern Golden Horn Collectors, the estuary does not receive any further wastewater (untreated sewage) from the northern side. By means of primary treatment at Baltalimaný plant, the sewerage water is deprived of coarse particles and floating materials, and subjected to deep sea discharge.

Currently, the Golden Horn Estuary is covered to 60 m depth with heavily contaminated sludge and sediment. The total amount of sludge is estimated to be 50 million cubic meters. On the other hand, the purification intends skimming up to 5 m depth. This depth is reduced down to 1 m along the shores for eliminating the sliding risk of surrounding buildings. The skimming operation is estimated to collect sludge of about 3 million cubic meters. Uptill now, 400,000 cubic meters of sludge has been transported to their ultimate landfill sites. In addition, desodorization of about 150 thousand cubic meters of sludge temporarily stored in stone mines around the site has been achieved by chlorination. These landfill sites will later be converted to recreational green fields.

The sludge will be dredged from the benthic region of the Ýstanbul Estuary (Golden Horn) and will be removed from the site without subjection to open air or turbidimetric mixing with water. Dredging methods will be selected to minimize turbulence within the water column. Restoration of aquatic life in the Golden Horn and reoxygenation of its waters are the goals. The project has been planned to finish by 1998, and the estimated cost is about US$125-130 million.

Bursa

The Metropolitan Municipality of Bursa (one of the five biggest cities of Turkey) has projected an investment of US$23 million (US$12.5 million of which is U.S. credit) covering the fulfillment of various tasks regarding industrial and domestic solid waste disposal. The following tasks have been planned under this project:

- Rehabilitation of the former uncontrolled dumping site (Demirtaþ refuse site)
- Construction and operation of regular solid waste disposal site (Hamitler storage site)
- Segregation and classification of wastes at source, covering wastes that can be further evaluated and sanitary wastes that can be incinerated
- Energy production from stored gas

Rehabilitation of Demirtaþ Uncontrolled Dumping Site

The site has served Bursa’s population for over 35 years. The project started in 1994, and the site has been closed to refuse dumping since 1996.

- The main body of the site (about 15 ha) has been resloped to orientate drainage water to bracing collectors.
- In order to prevent rainwater to penetrate into the mass, a final cover comprised of 0.30 m drainage layer, 0.40 m impermeable clay layer, and 0.40 m humic soil layer has been formed.
- 51 gas pipes have been mounted to collect the evolving gas from the storage area, and preparations have been made for potential energy production in 1998.
- Collecting forks have been laid at the foot of the slope (refuse hill) to receive the infiltrate water which is transported to the wastewater treatment plant after initial sedimentation.
- In order to prevent land erosion from flowing rainwater over the slopes, these slopes have been implanted.
- These operations in the former uncontrolled dumping site required US$2 million.

Construction of Hamitler Regular Disposal Site

The site (17 km from Bursa) includes 61 hectars of land capable of storing 8 million cubic meters of refuse, potentially meeting Bursa’s demand for 23 years.

- Construction began in 1994; two valleys (X and T) have been completed to enable regular refuse disposal.
- A drainage layer 0.30 m thick has been formed in both valleys to control groundwater pollution.
- The impermeable layer formed on top of the drainage layer is composed of 0.60 m clay + 2.5 mm HDPE in the X-valley, and of 1.20 m clay + HDPE in the T-valley. The water permeability of clay used was less than 10^{-8}.
- The infiltrate water is collected in impermeable ponds (of floor 0.60 m clay + 2.5 mm HDPE), and finally transported to the wastewater treatment plant after partial evaporation and volume reduction.
- These initial facilities at Hamitler site costed US$4 million. The approval of the daily intake of about a thousand ton refuse to these facilities has been initiated since mid 1996. The approvable solid wastes should have an analysis certificate (confirming their non-hazardous character) and are weighed in their trucks on the site. On the other hand, hazardous wastes that can be incinerated are taken to Ýzmit Incineration Plant.
- The infectious waste incineration facility at Hamitler has a built-in capacity of 300 kg/hr. The facility consists of two burning chambers, the first being operated with natural gas for preliminary burning, and the second capable of being elevated to 1,200°C in 2 seconds for final incineration.

Currently, sanitary wastes in special bags are transported to the regional incineration plant at Ýzmit in refrigerated containers.

Bursa’s projected sanitary waste capacity is 5,500 kg/day; the current collection capacity is at 2,400 kg/day.

3. Remedial Methods and RD&D

Currently, there are no reliable and comprehensive case study based statistics or data on remedial methods and technologies used for cleanup of soil and groundwater in Turkey. Regulatory aspects of acceptable remedial methods and technologies are provided by the *Control of Hazardous Wastes* regulation, which specifies acceptable remedial and/or disposal methods for a given type of contaminant group. In the *Control of Hazardous Wastes* regulation, acceptable methods for a large number of contaminant group is given as physical, chemical and biological treatment without stating the specific name of the method. However, it clearly states that use of remedial technologies is a must for wastes containing a large group of contaminants. Currently, there is no official knowledge regarding the widespread past use of particular technologies for soil and groundwater cleanup in Turkey. Most probably the remedial technologies that will be used for the Beykan, Incirlik and COPR Dump sites are going to be the first site specific examples and set precedence, in terms of both cost and performance, for cleanup in other similar sites.

There is a pressing need for research and development of soil and groundwater cleanup technologies in Turkey. This year, there is significant increase in the number of soil and groundwater remediation research projects supported financially by the Turkish *State Planning Organization*. Among this group, a project will be initiated on the performance assessment of S/S technology for remediation of a large waste group (*e.g.*, soils, mining waste and paper and pulp industry sludge) containing organic contaminants (PCB and AOX) and heavy metals. The main purpose of this project is to investigate the reliability of S/S technology for remediation of certain waste groups and provide technical and economical guidance for its field scale applications. Another component of this project is to emphasize consideration of the *risk-based corrective action* (RBCA) approach in the application of regulatory process for site specific cases. Considering the high cost of subsurface remediation problems, RBCA approach will offer significant savings compared to the current regulatory approach based on a fixed cleanup level.

4. Conclusions

There is a growing recognition of soil and groundwater degradation problems in Turkey. Because the enforcement of hazardous waste regulations is relatively new, some difficulties in the identification of soil and groundwater contamination sites remain unresolved. Recent regulatory efforts are helpful for identification of these sites contaminated as result of past activities. In the near future a considerable increase in the number of registered contaminated sites is expected.

Turkey presently relies heavily on surface water resources to satisfy water supply demands mainly because of relative abundance of surface waters resources. Groundwater constitutes a relatively small component of total available resources (10 percent) but it represents a significant portion (27 percent) of total water withdrawal. However, due to growing water demand parallel to rapid population and industrial growth, an increasing demand for food production, urban expansion and accelerated degradation of surface water quality, protection of clean groundwater resources as well as remediation of contaminated soil and groundwater sites are becoming environmental issues of high priority. The sustainable development of groundwater resources requires proper waste treatment for communities and industrial plants. Groundwater is the major source of drinking water supply and as such needs to be fully protected and allocated only for high quality uses. Although legislation on groundwater exists, their protection appears to be neglected at least in certain areas. With the spread of irrigation practices, the pollution threat to groundwater is also increasing. To date, unsatisfactory efforts has been made to protect groundwater from the increasing variety of potential pollution sources, such as agricultural chemicals, septic tanks, and waste dumps. The control of soil and groundwater contamination is essential to Turkey’s on-going reliance on groundwater resources for potable water.

The management of hazardous wastes in Turkey is inadequate to ensure proper handling and treatment. Industrial waste, particularly hazardous waste, has grown proportionately with industrial production. Treatment facilities are minimal and their disposal is usually haphazard. They pose serious dangers for soil and groundwater and in some cases for public health. The legal gap has to a certain extent has been filled with the regulation of the *Control of Hazardous Wastes*. Minimization of the generation and availability of facilities for proper storage and disposal of hazardous wastes has been embodied in this Turkish regulation. The policies are being strengthened by the application of such mechanisms of industrial waste management as the full implementation of environmental impact assessment for new proposals, the requirement that waste management programs be prepared and implemented by existing industries, and the encouragement of waste re-use.

UNITED KINGDOM

Introduction

This note provides a summary of contaminated land policy in the United Kingdom. It deals with:

- the basis of national policy
- who is responsible for controlling contaminated land
- existing controls
- Part IIA of the Environmental Protection Act 1990

There is also information on research and the major guidance on contaminated land which the Department of the Environment, Transport and the Regions expects to publish in 1998.

The Basis of National Policy

The control of contaminated land in the United Kingdom fits in with the Government's overall commitment to sustainable development and adherence to the precautionary principle. The "precautionary principle" is described in the 1990 white paper, *This Common Inheritance*, as meaning:

> "Where there are significant risks of damage to the environment, the Government will be prepared to take precautionary action to limit the use of potentially dangerous material or the spread of potentially dangerous pollutants, even where scientific knowledge is not conclusive, if the balance of likely costs and benefits justifies it."

More specifically, the details of the national policy on contaminated land were intimated in the document entitled *Framework for Contaminated Land* published in November 1994. The chief features of the policy are:

- Most importantly, there have to be adequate controls in place to prevent land contamination in the first place. This is achieved through Integrated Pollution Control and waste management licensing.

- With regard to existing contamination, the rule should be that the land is "suitable for use"—remedial action is required only where the *current or intended use* of the site presents unacceptable risks to health or the environment, and where there are appropriate and cost effective means of undertaking remediation.

- The normal processes of development and redevelopment of land are the best means of tackling much past contamination, with those developments being subject to the planning control and building regulation systems.

- Broadly speaking, the "polluter pays" principle should guide the application of liabilities for the cost of remediating contaminated land.

Responsibilities for Controlling Contaminated Land

The box below describes the public sector's responsibilities for controlling contaminated land in the United Kingdom. The polluter, or in some cases the owner or occupier of the land, is responsible for paying for the cost of remedying the pollution.

Body	**Responsibility**
Department of the Environment, Transport and the Regions/Scottish Office	Responsible for setting national policy. Publishes guidance. Finances costs of local authorities' activities in respect of contaminated land. Through English Partnerships and (in future) Regional Development Agencies funds remediation in particular circumstances.
Environment Agency/Scottish Environment Protection Agency (SEPA)	Responsible for Integrated Pollution Control and waste management licencing. Also responsible for the condition of controlled waters. Takes an overview of contaminated land nationally. Gives site-specific advice about contamination to local authorities. Will be directly responsible for "special sites" when Part IIA of the Environmental Protection Act 1990 is brought into operation. Undertakes technical research.
Local authorities	Responsible for planning and building control. Also responsible under "statutory nuisance" and (when it replaces statutory nuisance) Part IIA for identifying contaminated land and, where necessary, securing its remediation.

Northern Ireland has the same basic policy for controlling contaminated land but its institutional structure is somewhat different.

Existing Controls

Integrated Pollution Control and waste management licensing. Very basically, operators of "prescribed industrial processes" require authorisations to undertake their activities and operators of waste management sites require licences. Authorisations and licences are issued by the Environment Agency (in England and Wales) and SEPA (in Scotland), are subject to conditions and may be withheld or cancelled.

Planning control. Contamination or the potential for contamination can be a material planning consideration and should be taken into consideration by the local (planning) authority at both the macro (development plan) and micro (determination of individual planning applications) levels of the planning process. The onus is on the developer to provide the authority with details of any contamination. Planning permission may be granted on condition that the site is remediated to the satisfaction of the local authority. Responsibility for the safe development and secure occupancy of the site rests with the developer.

Building control. In addition to its planning function, the local authority also enforces the Building Regulations. Requirement A of the Building Regulations requires that buildings are structurally sound and requirement C states that "precautions should be taken to avoid danger to health and safety caused by substances found on or in the ground to be covered by a building."

"Statutory Nuisance". Lastly, local authorities have a duty to regulate various matters which are defined as statutory nuisance. These include odour, noise and, relevant to contaminated land, accumulations or deposits on land which are prejudicial to health or a nuisance. When an authority identifies a statutory nuisance, it has a duty to serve on the person "responsible for the nuisance" or, in some cases, on the owner or occupier of the premises, an abatement notice requiring steps to be carried out to prevent or reduce the nuisance. Should the notice not be complied with, the authority can carry out the works itself and recover its costs.

Part IIA of the Environmental Protection Act of 1990

The Government announced on 22 December 1997 that it had concluded that Part IIA of the Environmental Protection Act 1990 (inserted by section 57 of the Environment Act 1995 and passed by the previous Government) sets out, in principle, broadly the right framework for controlling land that in its current use poses health or environmental dangers. Part IIA is modelled on the existing statutory nuisance provisions and will replace them in respect of contaminated land. The timetable for the implementation of Part IIA will be decided by the Government after it has concluded its present Comprehensive Spending Review.

Local authorities will cause their areas to be inspected in order to identify contaminated land and they will ensure that appropriate remediation takes place when they identify such land.

Contaminated land is identified on the basis of risk assessment. Land is only "contaminated land" where it appears to the authority, by reason of the substances in, on or under the land, that :

(a) significant harm is being caused or there is a significant possibility of such harm being caused; or

(b) pollution of controlled waters is being, or is likely to be caused.

Where necessary, authorities will ensure that appropriate remediation is undertaken by serving a remediation notice. Such a notice is served on any person who "caused or knowingly permitted" the substances causing the land to be contaminated to be present. If no such person can be found, the notice has to be served on the owner or occupier of the land. The provisions allow for the apportionment of liability where there is more than one polluter. Failure to comply with a remediation notice is an offence.

However, a person who is the owner or occupier of the land cannot be required, under this legislation, to carry out remediation which is needed to only deal with water pollution. This is dealt with by separate legislation to cover the protection of water resources. For example, in England and Wales, the Environment Agency will be able to serve a works notice using the Water Resources Act 1991 (the amended Section 161A-D) to ensure that pollution prevention, and where necessary remediation measures, are taken by responsible parties in respect of water pollution.

In some circumstances the authority can carry out the remediation itself and recover its costs from the persons or persons liable.

In setting any remediation requirements, an authority has to have regard to the costs which are likely to be involved and to the seriousness of the relevant harm or water pollution. The authority also has to consider whether the person liable for carrying out the remediation might suffer financial hardship if he did the work. If so, the cost to him is waived or reduced, and the cost is met by the local authority.

The Environment Agencies are responsible for dealing with "special sites". In essence, these are sites which are defined as contaminated land under Part IIA and which the Agencies are already involved with regulating through pollution control legislation (though not all waste disposal sites are included) or for which the Agencies have historical expertise and knowledge, or where particular sensitivities apply.

In carrying out their duties local authorities have to have regard to statutory guidance to be issued by the Secretary of State for the Environment, Transport and the Regions. Draft statutory guidance was made available for consultation in September 1996.

Research on Contaminated Land

The Environment Agency carries out a significant programme of research into contaminated land, which was inherited from the Department of the Environment, Transport and the Regions. The Programme focuses on the production of best practice guidance to support the proposed new regulatory regime. Specifically, the Research Programme:

- develops current scientific knowledge on risk assessment and risk management of contaminated land (with particular emphasis on issues of sustainability and a consideration of the costs and benefits);
- develops procedures for the effective delivery of regulatory activities in land contamination;
- reviews and identifies information needs for the preparation of a report on the state of contaminated land in England and Wales.

Collaboration with other organisations is sought, where appropriate, to achieve the Programme objectives. The Research Programme also takes account of work in other countries and of possibilities for the UK to influence and contribute to important international developments in this area.

Publications on Contaminated Land in 1998

Details of UK publications on contaminated land are available upon request. Among the reports the Department of the Environment, Transport and the Regions plans to publish this year are reports on:

- the collation of toxicological information on substances frequently encountered as contaminants in the UK;
- the operation of the CLEA (Contaminated Land Exposure Assessment) model developed for the Department by The Centre for Research into the Built Environment Ltd, Nottingham Trent University. Guideline values for protection of human health derived from CLEA will be published for a number of specific contaminants;
- “model procedures” for the management of contaminated land, integrating current good practice guidance into a series of logical and structured activities that might be adopted by those responsible for managing contaminated land.

UNITED STATES OF AMERICA

1. Legal and Administrative Issues

Three different federal programs provide the authority to respond to threatened releases of hazardous substances that endanger public health or the environment: (1) In response to a growing concern about contaminated sites, Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in 1980. Commonly known as Superfund, the program under this law is the central focus of federal efforts to clean up releases of hazardous substances at abandoned or uncontrolled hazardous waste sites. The program is funded, in part, by a trust fund based on taxes on the petroleum and other basic organic and inorganic chemicals. (2) The second program is directed at corrective action at currently operating industrial facilities. This program is authorized by the Resource Conservation and Recovery Act of 1980 (RCRA) and its subsequent amendments. This law also regulates the generation, treatment, storage and disposal of hazardous waste at industrial facilities. RCRA corrective action sites tend to have the same general types of waste as Superfund sites, and environmental problems are generally less severe than at Superfund sites; although some RCRA facilities have corrective action problems that could equal or exceed those of many Superfund sites. (3) The third cleanup program, also authorized by RCRA, addresses contamination resulting from leaks and spills (primarily petroleum products) from underground storage tanks (USTs). This law has compelled cleanup activities at many UST sites. By the end of 1996, over 300,000 confirmed releases had been reported, over 250,000 cleanups initiated, and over 150,000 cleanups completed.

<u>Implementation of Hazardous Waste Cleanup Legislation</u>

Each cleanup program has a formal process for identifying, characterizing, and cleaning up contaminated sites. These processes generally involve joint implementation with state agencies and the involvement of various groups, such as local government agencies, local residents, businesses, and environmental public interest groups. Superfund is administered by EPA and the states under the authority of the CERCLA. The procedures for implementing the provisions of CERCLA substantially affect those used by other federal and state cleanup programs. These procedures are spelled out in the National Oil and Hazardous Substances Pollution Contingency Plan, commonly referred to as the National Contingency Plan (NCP). The NCP outlines the steps that EPA and other federal agencies must follow in responding to “releases” of hazardous substances or oil into the environment. Although the terminology may differ from one program to another, each follows a process more-or-less similar to this one. Thus, in addition to comprising a defined single program, activities in the Superfund program substantially influence the implementation of the other remediation programs.

RCRA assigns the responsibility for corrective action to facility owners and operators and authorizes EPA to oversee corrective action. Unlike Superfund, RCRA responsibility is delegated to sates. As of the end of 1996, EPA has authorized 32 states and territories to implement RCRA corrective action. The processes for characterizing and remediating RCRA corrective action sites are analogous to those used for Superfund sites, although the specific terminology and details differ.

The UST regulations require tank owners to monitor the status of their facilities and immediately report leaks or spills to the regulatory authority, which usually is the state. Cleanup requirements generally are similar to those under RCRA corrective action and are entirely overseen by state agencies.

Anticipated Policy Developments.

The nature and scope of remediation policies are driven largely by federal and state requirements and public and private expenditures. A number of legislative and regulatory initiatives may affect the operation of the Superfund, RCRA corrective action, and UST programs. For example, some of the proposed changes to Superfund would require consideration of land use in setting cleanup standards, emphasize the treatment and disposal of only the highly contaminated and highly mobile media, limit the addition of new sites to the Superfund remediation program, and change the liability aspect of CERCLA to reduce the cost and time needed to assign the liability for a cleanup project. Some of these changes have already being implemented, to some extent, under EPA administrative reforms. Congress and EPA also are considering proposals to revise RCRA to exempt wastes from remediation activities from certain hazardous waste management requirements, streamline the permitting process, and modify land disposal restrictions.

There is widespread and growing interest in using risk assessment to determine cleanup priorities, as may be done under the Risk Based Corrective Action initiative in the UST program. There is also increasing interest in the issue of bioavailability of contaminants as an alternative to chemical concentrations alone to set cleanup standards. Much scientific work and consensus-building has yet to be completed on this issue. Finally, the “Brownfields” policy initiative has become prominent at the federal and state levels. This concept uses economic redevelopment as the driving force for site cleanup and is gaining widespread acceptance.

2. Identification of Contaminated Sites

Almost half a million sites with potential contamination have been reported to state or federal authorities over the past 15 years. Of these, about 217,000 still require remediation for which contracts have not been issued. Almost 300,000 other sites were either cleaned up or were found to require no further action. Regulatory authorities have identified most of the contaminated sites. Nevertheless, new ones continue to be reported each year, but at a declining rate. The data on number of sites come from disparate sources because these sites are not all registered in one data repository. EPA maintains detailed data on Superfund sites and summary information for RCRA corrective action and UST sites. The states and other federal agencies generally maintain separate records of the sites for which they are responsible. It is estimated that the cost of remediating the 217,000 sites will be about $187 billion in 1996 dollars, and that it will take at least several decades to completely remediate all the identified sites.

3. Remediation Technologies

Historical Remedial Technology Use in the U.S.

Solidification/stabilization has been the most common technology to treat soil and other wastes. It has been the favored technology to treat metal-containing waste, although its selection has declined in the last two years. Relatively few alternative technologies have been selected for metals. Solidification/stabilization has been the most frequently selected technology to treat organic contaminants, primarily semivolatile organics (SVOCs). Incineration has been the second most frequently selected of any technology for treating soil, sludge, and sediment in Superfund. The major advantage of incineration is its ability to achieve stringent cleanup standards for highly concentrated mixtures. The selection of on-site incineration has declined to less than four percent of source control technologies selected from 1993 through 1995, primarily because of its cost and a lack of public acceptance. Off-site incineration, the use of which also has dropped, is feasible for only relatively small waste quantities.

Trends and Anticipated Remedial Technology Use

After a significant increase in the selection of treatment technologies, especially innovative technologies, in the early 1990s, the selection of several technologies has leveled off or decreased in the past two years, and the selection of containment has become more common. Most of the applications of innovative technologies for Superfund cleanups have been to treat organic contamination in soil. Three innovative technologies account for over 75 percent of innovative technology applications:

- Soil vapor extraction (SVE), which is primarily used to treat VOCs, is the most commonly used innovative technology. The selection of SVE relative to other technologies grew rapidly from 1986 to 1989, fluctuated for the next few years, and declined in 1995. Enhancements, such as methods to increase soil permeability or contaminant volatility, may expand its applicability and improve performance.

- Bioremediation is the second most frequently selected innovative technology, and its selection has remained fairly constant over the past several years. This trend may reflect a limit in the number of sites with contaminants that can be treated by bioremediation in its current state of development. The contaminants most often treated by bioremediation are petroleum hydrocarbons and PAHs. Current bioremediation research could lead to improved performance and expand the types of contaminants amenable to biological degradation.

- Thermal desorption is the third most frequently selected innovative technology. The frequency of selection for this technology has remained relatively constant over the past five years. It is used primarily to treat VOCs, (particularly when SVE is not feasible), and SVOCs, primarily PAHs and PCBs. Soils containing both metals and organics present another major treatment opportunity, since organics will volatize at relatively low temperatures. Residuals containing metals then can be treated by another technology, such as solidification/stabilization.

Relatively few innovative treatment methods are being selected for metals-contaminated soils. The most widely used technology for the treatment of metals is solidification/stabilization, which has been selected for 30 percent of the source control projects at Superfund sites. The selection of this technology has declined during the past two years. Although solidification/stabilization has several advantages, including low cost, questions remain concerning its effectiveness over time. Consequently, the sites may require long-term monitoring. New separation technologies such as electrokinetics could provide alternative methods for remediating metals in the future. Additional field tests of these and other technologies are needed.

Despite recent advances, about 93 percent of remedies selected for groundwater continue to rely on conventional pump-and-treat technologies. Bioremediation and air sparging are the most widely used innovative *in situ* approaches. Usually, these technologies are applied in conjunction with pump-and-treat. Research and demonstration efforts to develop innovative methods for the treatment of ground-water include both biological and abiotic *in situ* processes.

4. Research, Development, and Demonstration

Future technology use will be influenced by development efforts and the expressed needs of industry and other entities with responsibility for site cleanups. Federal agencies currently are coordinating several technology development and commercialization programs. Of these, two cooperative public-private initiatives are particularly noteworthy because they focus on processes that private "problem holders" view as most promising for the future. The involvement of technology users helps to assure that the processes selected for development reflect actual needs and have a high potential for future application. The technologies identified by these programs and federal agencies provide a useful overview of future trends.

The Remediation Technologies Development Forum (RTDF) is a consortium of partners from industry, government agencies, and academia, who share the common goal of developing more effective, less costly hazardous waste characterization and treatment technologies. RTDF achieves this goal by identifying high priority needs for remediation technology development. Through the Clean Sites Public-Private Partnerships for technology acceptance, EPA and Clean Sites, Inc., a nonprofit firm, develop partnerships between federal agencies (such as DOD and DOE) and private site owners (responsible parties, owners/operators) for the joint evaluation of full-scale remediation technologies. The purpose of this program is to create a demand among potential users of new technologies by allowing. the end-users of the technologies to be involved throughout the demonstration process.

DOE is spending $274 million in Fiscal Year 1998 to develop new environmental cleanup technologies. A recent DOE report described 15 new technologies, scheduled to be available by 2000, that may lead to cost savings in cleaning up DOE sites. These technologies are specific examples of the types of technologies that DOE expects to need in the near future, such as bioremediation, electrokinetics, and biosorption of uranium.

The technologies selected for development in these three programs demonstrate that prospective users are interested in using *in situ* processes and biotechnology to meet their future needs (Table 1). Various biological methods often are cited, especially for chlorinated solvents. Several technologies rely on SVE as a component, including dual-phase extraction, air sparging, dynamic underground stripping, and rotary steam drilling. Also, several processes entail the creation of treatment zones (permeable barriers, microbial filters, and the Lasagna™ process) and the use of electric fields to mobilize both organics and inorganics.

DOD has several technology research and development programs targeted at helping commercialize remediation technologies. The Environmental Security Technology Certification Program (ESTCP) is designed to promote the demonstration and validation of the most promising innovative technologies that target DOD's most urgent environmental needs. It is funded at $15 million per year. The Strategic Environmental Research and Development Program (SERDP) is a joint program with DOD, DOE, and EPA—funded at $61.8 million per year—which devotes 31 percent of its resources to remediation and site characterization technologies. In 1998, the Advanced Applied Technology Demonstration Facility program concludes after sponsoring demonstrations of 12 technologies for DOD at a cost of $20 million. DOD's high priority cleanup technology needs include: detection, monitoring and modeling (primarily related to unexploded ordnance [UXO] and DNAPLS); treatment for soil, sediment, and sludge (primarily related to UXO, white phosphorous contaminated sediments, inorganics, explosives in soil, explosives/organic contaminants in sediments); groundwater treatment (explosives, solvents, organics, alternatives to pump-and-treat, and DNAPLS); and removal of UXO on land and under water.

5. Conclusions

Legislative, regulatory and programmatic changes may alter the nature and sequence of cleanup work done at Superfund, DOD, and DOE sites. If some of the current proposals become law, more emphasis may be placed on cleaning up the most severely contaminated areas on a site, making government properties available for economic reuse, increased consideration of future land use in remedy selection, and more explicit consideration of cost and performance in remedy decisions.

After a significant increase in the selection of newer treatment technologies—such as SVE, thermal desorption, and bioremediation—in the early 1990s, the selection of several technologies has leveled off or decreased in the past two years, and the selection of containment has become more common. Nevertheless, treatment remedies still are more common.

New technologies offer the potential to be more cost-effective than conventional approaches. *In situ* technologies, in particular, are in large demand because they are usually less expensive and more acceptable than above-ground options. New technology development programs emphasize *in situ* technologies, in particular bioremediation and enhancements to SVE.

Although metals are common at most sites, alternatives to treat metals are limited. Government and corporate owners of contaminated sites have targeted several technologies to treat metals in soil for further development, including electrokinetics and phytoremediation.

While groundwater is contaminated at more than 70 percent of the sites, not all of these sites will be actively remediated. Available technology cannot always meet the desired cleanup goals for a site, because the methods leave residual aquifer contamination, known as non-aqueous phase liquids (NAPLs). The most frequently used method for groundwater remediation at Superfund sites is conventional pump-and-treat technology. *In situ* treatment technologies, primarily bioremediation and air sparging, have been selected at only six percent of Superfund groundwater treatment sites, most of which also are using pump-and-treat. New management approaches recently receiving more attention include treatment walls, electrokinetics, use of surfactants and co-solvents, hydraulic and pneumatic fracturing, and selective application of natural attenuation. If more effective *in situ* groundwater technologies were available, a larger portion of contaminated groundwater sites could be fully remediated.

Table 1. Examples of Technology Needs Identified by Users in Selected Federal Programs

Medium	Clean Sites Public-Private Partnerships	Remediation Technologies Development Forum	Department of Energy
In Situ Management of Soils	• Lasagna™ (electroosmosis, hydrofracturing treatment zones)	• Lasagna™ • Co-metabolic bioventing • Phytoremediation for metals	• Electrokinetics • Vitrification
In Situ Management of Groundwater	• Anaerobic bioremediation • Permeable treatment walls • Air sparging	• Accelerated anaerobic bioremediation • Permeable treatment walls • Intrinsic bioremediation	• Recirculating wells • Microbial filters • Bioremediation • Biosorption of uranium
In Situ Management of Soil and Groundwater	• Rotary steam drilling • Dual-phase extraction	• Not applicable	• Dynamic underground stripping
Ex Situ Management of Soil	• Enhanced bioslurry reactors	• Not applicable	• Innovative soil washing
Ex Situ Management of Groundwater	• Membrane separation	• Not applicable	• Not applicable

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PILOT STUDY MISSION

PHASE III — Continuation of NATO/CCMS Pilot Study: Evaluation of Demonstrated and Emerging Technologies for the Treatment of Contaminated Land and Groundwater

1) Background To Proposed Study

The problems of contamination resulting from inappropriate handling of wastes, including accidental releases, are faced to some extent by all countries. The need for cost-effective technologies to apply to these problems has resulted in the application of new/innovative technologies and/or new applications of existing technologies. In many countries, there is increasingly a need to justify specific projects and explain their broad benefits given the priorities for limited environmental budgets. Thus, the environmental merit and associated cost-effectiveness of the proposed solution will be important in the technology selection decision.

Building a knowledge base so that innovative and emerging technologies are identified is the impetus for the NATO/CCMS Pilot Study on "Evaluation of Demonstrated and Emerging Technologies for the Treatment of Contaminated Land and Groundwater." Under this current study, new technologies being developed, demonstrated, and evaluated in the field are discussed. This allows each of the participating countries to have access to an inventory of applications of individual technologies which allows each country to target scarce internal resources at unmet needs for technology development. The technologies include biological, chemical, physical, containment, solidification/stabilization, and thermal technologies for both soil and groundwater. This current pilot study draws from an extremely broad representation and the follow up would work to expand this.

The current study has examined over fifty environmental projects. There were nine fellowships awarded to the study. A team of pilot study country representatives and fellows is currently preparing an extensive report of the pilot study activities. Numerous presentations and publications reported about the pilot study activities over the five year period. In addition to participation from NATO countries; NACC, other European, and Asian-Pacific countries participated. This diverse group promoted an excellent atmosphere for technology exchange. An extension of the pilot study will provide a platform for continued discussions in this environmentally challenging arena.

2) Purpose and Objectives

The United States proposes a follow-up (Phase III) study to the existing NATO/CCMS study titled "Evaluation of Demonstrated and Emerging Technologies for the Treatment of Contaminated Land and Groundwater." The focus of Phase III would be the technical approaches for addressing the treatment of contaminated land and groundwater. This phase would draw on the information presented under the prior studies and the expertise of the participants from all countries. The output would be summary documents addressing cleanup problems and the array of currently available and newly emerging technical solutions. The Phase III study would be technologically orientated and would continue to address technologies. Issues of sustainability, environmental merit, and cost-effectiveness would be enthusiastically addressed. Principles of sustainability address the use of our natural resources. Site remediation addresses the management of our land and water resources. Sustainable development addresses the re-use of contaminated land instead of the utilization of new land. This appeals to a wide range of interests because it combines economic development and environmental protection into a single system. The objectives of the study are to critically evaluate technologies, promote the appropriate use of technologies, use information technology systems to disseminate the products, and to foster innovative thinking in the area of contaminated land. International technology verification is another issue that will enable technology users to be assured of minimal technology performance. This is another important issue concerning use of innovative technologies. This Phase III study would have the following goals:

a) In-depth discussions about specific types of contaminated land problems (successes and failures) and the suggested technical solutions from each country's perspective,

b) Examination of selection criteria for treatment and cleanup technologies for individual projects,

c) Expand mechanisms and channels for technology information transfer, such as the NATO/CCMS Environmental Clearinghouse System,

d) Examination/identification of innovative technologies,

e) Examining the sustainable use of remedial technologies—looking at the broad environmental significance of the project, thus the environmental merit and appropriateness of the individual project.

3) Estimated Duration

November 1997 to November 2002 for meetings.
Completion of final report: June 2003.

4) Scope of Work

First, the Phase III study would enable participating countries to continue to present and exchange technical information on demonstrated technologies for the cleanup of contaminated land and groundwater. During the Phase II study, these technical information exchanges benefitted both the countries themselves and technology developers from various countries. This technology information exchange and assistance to technology developers would therefore continue. Emphasis would be on making the pilot study information available. Use of existing environmental data systems such as the NATO/CCMS Environmental Clearinghouse System will be pursued. The study would also pursue the development of linkages to other international initiatives on contaminated land remediation.

As in the Phase II study, projects would be presented for consideration and, if accepted by other countries, they would be discussed at the meetings and later documented. Currently, various countries support development of hazardous waste treatment/cleanup technologies by governmental assistance and private funds. This part of the study would report on and exchange information of ongoing work in the development of new technologies in this area. As with the current study, projects would be presented for consideration and if accepted, fully discussed at the meetings. Individual countries can bring experts to report on projects that they are conducting. A final report would be prepared on each project or category of projects (such as thermal, biological, containment, etc.) and compiled as the final study report.

Third, the Phase III study would identify specific contaminated land problems and examine these problems in depth. The pilot study members would put forth specific problems, which would be addressed in depth by the pilot study members at the meetings. Thus, a country could present a specific problem such as contamination at a electronics manufacturing facility, agricultural production, organic chemical facility, manufactured gas plant, etc. Solutions and technology selection criteria to address these problems would be developed based on the collaboration of international experts. These discussions would be extremely beneficial for the newly industrializing countries facing cleanup issues related to privatization as well as developing countries. Discussions should also focus on the implementation of incorrect solutions for specific projects. The documentation of these failures and the technical understanding of why the project failed will be beneficial for those with similar problems. Sustainability, environmental merit, and cost-benefit aspects would equally be addressed.

Finally, specific area themes for each meeting could be developed. These topics could be addressed in one-day workshops as part of the CCMS meeting. These topic areas would be selected and developed by the pilot study participants prior to the meetings. These areas would be excellent venues for expert speakers and would encourage excellent interchange of ideas.

5) Non-NATO Participation

It is proposed that non-NATO countries be invited to participate or be observers at this NATO/CCMS Pilot Study. Proposed countries may be Brazil, Japan, and those from Central and Eastern Europe. It is proposed the non-NATO countries (Austria, Australia, Sweden, Switzerland, New Zealand, Hungary, Slovenia, Russian Federation, *etc.*) participating in Phase II be extended for participation in Phase III of the pilot study. Continued involvement of Cooperation Partner countries will be pursued.

6) Request for Pilot Study Establishment

It is requested of the Committee on the Challenges of Modern Society that they approve the establishment of the Phase III Continuation of the Pilot Study on the Demonstration of Remedial Action Technologies for Contaminated Land and Groundwater.

Pilot Country: United States of America
Lead Organization: U.S. Environmental Protection Agency

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Co-Partner Countries: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Japan, New Zealand, Norway, Poland, Portugal, Slovenia, Sweden, Switzerland, The Netherlands, Turkey, United Kingdom, United States

Scheduled Meetings: February 23-27, 1998, in Vienna, Austria
1999 to be determined
2000 in France or Germany
2001 in Canada or the United States