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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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NATO/CCMS Pilot Study

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

Angers, France
May 9-14, 1999

September 1999

NOTICE

This Annual 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 report was funded by U.S. EPA's Technology Innovation Office under the direction of Ann Eleanor. The report was 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 reports on the second 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. 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 were published in June 1998. Through these pilot studies, critical technical information was made available to participating countries and the world community.

The Phase III study focuses on the technologies for treating contaminated land and groundwater. This Phase is addressing 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 was held in Vienna, Austria, on February 23-27, 1998. The meeting included a special technical session on treatment walls and permeable reactive barriers. The proceedings of the meeting and a companion document on the special technical session were published in May 1998.

The second meeting of the Phase III Pilot Study convened in Angers, France, on May 9-14, 1999, with representatives of 18 countries attending. Ten of the participating countries presented 15 projects to the Pilot Study. These projects were discussed and commented on by experts. Five additional projects were also proposed and selected for inclusion in the Pilot Study. A special technical session was convened on monitored natural attenuation. The proceedings of that special session are available in a companion publication.

This publication represents the second Annual Report of the Phase III Pilot Study. It contains updated summaries of the 20 projects as well as reports on the legislative, regulatory, programmatic, and research issues related to contaminated land in each participating country.

You can obtain general information on the NATO/CCMS Pilot Study from the Country Representatives listed at the end of this report. For detailed questions on an individual project, please consult the technical contact listed in each project summary. Many of the Pilot Study reports are also available online at http://www.nato.int/ccms/.

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

PROJECTS INCLUDED IN NATO/CCMS PHASE III PILOT STUDY

SUMMARY TABLE

		MEDIUM		CONTAMINANT						
PROJECT	**COUNTRY**	Soil	Groundwater	VOCs	SVOCs	Pesticides/PCBs	PHCs	Inorganics	**NOTES**	**COMPLETE**
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. Thermal Cleanups Using Dynamic Underground Stripping and Hydrous Pyrolysis/Oxidation	USA	✓	✓	✓		✓			PAHs, fuels, gasoline, chlorinated solvents, pentachlorophenol	✓

		MEDIUM		CONTAMINANT						
PROJECT	COUNTRY	Soil	Groundwater	VOCs	SVOCs	Pesticides/PCBs	PHCs	Inorganics	NOTES	COMPLETE
15. Phytoremediation of Chlorinated Solvents	USA		✓	✓					TCE, TCA, DCE, PCE, xylenes, methyl chloride, TMB	
16. In-Situ Heavy Metal Precipitation	Belgium		✓					✓	Heavy Metals (Zn, Cd, As, Pb, Cr, Ni, Cu, sulfate)	
17. Gerber Site	France	✓	✓	✓	✓	✓		✓	Chlorinated solvents, BTEX, PCBs, phenols, phthalates, Pb, Zn	
18. SAFIRA	Germany		✓	✓					Complex contamination, chlorobenzene	
19. Successive Extraction - Decontamination of Leather Tanning Waste Deposited Soil	Turkey			✓				✓	Tanning Wastes	
20. Interagency DNAPL Consortium Side-by-Side Technology Demonstrations at Cape Canaveral, FL	USA		✓	✓					DNAPLs	

KEY:

AOX = adsorptive organic halogens
BTEX = benzene, toluene, ethylbenzene, and xylenes
DCE = dichloroethene
HCH = hexachlorocyclohexane
PAHs = polycyclic aromatic hydrocarbons
PCBs = polychlorinated biphenyls
PCE = tetrachloroethene
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 Oil Polluted Loamy Soil</td></tr>
<tr><td>Location
“van Oss” site
former fuel storage depot
Neder-Over-Heembeeck</td><td>Project Status
final report
proposal future pilot project</td><td>Media
loamy soil</td><td>Technology Type
bioremediation</td></tr>
<tr><td rowspan="2">Technical contact
Ecorem nv
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Tel: 015/29.49.29
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E-mail: Ecorem@glo.be</td><td>Project Dates
accepted 1994
final Report 1997</td><td colspan="2">Contaminants
mineral oil</td></tr>
<tr><td>Costs Documented?
yes</td><td colspan="2">Project Size
full scale
(proposal future pilot project)</td></tr>
</table>

1. INTRODUCTION

Name of the technology: Bioremediation of oil polluted loamy soil.

Status of the technology: Highly innovative and reasonable costs. Further experiments are required to evaluate different bioremediation techniques for the decontamination of loamy soil.

Project Objectives: Decontamination of oil polluted loamy soil by an in-situ activated biorestoration system, composed of a bioventing and a biostimulation system.

Following the good decontamination results on the van Oss site, this project is considered as a first step towards a more general and more effective application of bioremediation of contaminated loamy soils. In collaboration with the ULB (Université libre de Bruxelles) Ecorem proposed a pilot project to NATO, with objective to examine which bioremediation techniques could efficiently be used in the decontamination of loamy soils polluted with hydrocarbons.

2. SITE DESCRIPTIONS

The van Oss site is a former fuel storage depot in Neder-over-Heembeek, contaminated with mineral oil. A topographical situation of the site is shown on **FIGURE 1**.

3. DESCRIPTION OF THE PROCESS

Based upon a reconnoitring soil examination, it was proven that the soil as well as the groundwater of the former fuel storage depot « van Oss » was seriously contaminated with mineral oil. Compared to the contamination with this parameter, the presence of other components present was negligible.

The volume of contaminated soil (unsaturated zone) was estimated, based on the reconnoitring soil examination, at 3.500m³. Proceeding with these data, selective excavation of the contaminated zones was a first option to be considered.

In order to draw up a detailed proposal for decontamination, Ecorem proposed an elaborated analysis campaign based on a sample grid.

Based on the analytical results and the positioning of the grid the volume of contaminated soil was assessed. **Table 1** gives an overview of the volumes of contaminated soil. In **Figure 3** the horizontal spreading of the mineral oil contamination in the soil is represented.

Table 1 Overview of the volumes of contaminated soil (mineral oil)

	>525mg/kg DES	*>1000 mg/kg DS*	*>5000mg/kg DS*
Depth (cm)			
0-200	9231m³	6284m³	943 m³
	14770 tons	10054 tons	1509 tons
0-250	10997m³	6997m³	1050m³
	17995 tons	11196 tons	1680 tons
0-300	12763m³	7711m³	1156m³
	20420 tons	12338 tons	1850 tons

The cubing shows that the volumes of contaminated soil were considerably higher than estimated at first. As a result, Ecorem proposed an alternative decontamination technique, i.e. an in-situ activated biorestoration system composed of a bioventing and a biostimulation system. Bioventing consists of a forced air flushing of the unsaturated soil with as main objective the supply of oxygen in order to stimulate the biodegrading activity of the microorganisms present in the soil. The biostimulation in this project consisted of mixing the contaminated ground with compost and wood flakes, in order to obtain a porous matrix, and the addition of nutrients to enhance microbial activity.

Decontamination of the unsaturated zone consisted of the following stages:

a) Excavation of the hot spots

Hot spots (areas with severe contamination - here areas where the concentration of mineral oil >5000mg/kg DS) are secondary sources of contamination, and can therefore inhibit the efficient functioning of an in-situ decontamination technique. It is thus essential that these secondary sources of contamination are removed, for the in-situ decontamination technique to have any chance of success.

b) Biodegradation

The efficiency of the biodegradation system strongly depends on soil characteristics. In order to obtain a good biological degrading, the oxygen level and level of nutrients need to be established in optima forma.

A good supply of oxygen can only be realised in porous soils. Soils with limited air permeability, such as loamy soils, therefore need to be mixed with structure amelioration additives. Oxygen is necessary for hydrocarbon degradation, as this is done aerobically. Oxygen limitation leads to slowing down and discontinuing of the degradation kinetics. The creation of good air permeability is also of crucial importance for the bioventing.

A second parameter, the nutrient supply is just as essential for a good biodegradation. In order to optimise the feeding pattern the soil should be mixed with bioactivating substrates.

c) Soil air extraction

The efficiency and the design of the soil air extraction strongly depend on the soil characteristics, as these have an important effect on the movement and transportation of soil air (gas). The most important determining soil characteristics are: soil structure, stratigraphy, porosity, grain size; water level, residual contamination and presence of macro pores.

The air permeability of the soil represents the effect of these different soil characteristics. The air permeability indicates to what extent fumes can float through a porous environment.

Air permeability and airflow velocity are linearly dependent. The higher the air permeability and the airflow velocity, the greater the chances of an effective soil air extraction.

Taking into account that the loamy / clayey unsaturated zone at the van Oss site is heterogeneously built, the air transportation throughout the soil is prevented and the airflow velocity is relatively small. A solution to break this heterogeneity was to mix this oil with structure-enhancing additives till the depth of 0.5 m above ground water level. This also enlarged the porosity of the soil, which was favourable for air transportation.

In order to get a large zone of influence, the placement of horizontal injection and withdrawal drains was chosen. Placement of drains was performed in layers, the soil mixed with structure-enhancing additives being completed (**FIGURE 2**)

The withdrawn air was purified in an air treatment establishment, consisting of following units:

- Air/water separator and air filter

  This separator and filter eliminates soil damp (water) and fine particles that may damage the mechanical equipment, and might disrupt further air treatment. The water discerned needs to be collected and, if contaminated, purified.

- Vacuum pump

  The vacuum pump causes the suction in the underground. The compression heat in the pump causes a temperature increase and a corresponding decrease of the relative humidity of the airflow when leaving the blower.

- Air cleaning unit

  The pumped up air was treated by means of biofiltration and active carbon filtration.

- Measure devices

  By measuring the different parameters the air treatment and soil air extraction could constantly be monitored and adjusted.

The above mentioned decontamination concept has a double advantage:

- It avoids transportation of considerable volumes of contaminated soil (approx. 12.000 tons with a concentration higher than 1000mgkg DM) to an adapted dumping-ground;

- It relocates the problem of the desired quality from a problem of volume to a problem of time. The final quality of the soil is function of the time period in which the system is applied.

The complete decontamination setting is represented in **FIGURE 2**.

4. RESULTS AND EVALUATION

The bioremediation of the unsaturated zone was started in October 1995, after the hot spots had been excavated and the remaining soil had been mixed with compost and wood flakes. After two months a first analysis campaign was executed. The results have been visually represented in **FIGURE 3**. Further analysis campaigns were executed after 5 and after 10 months. These results have been represented in **FIGURE 4** and **FIGURE 5**. Based on the visual representation of the horizontal spread of the contamination in the different figures it has become clear that the bioremediation technique is successful.

After ten months the mean concentration of mineral oil was less than 490 ppm, while the decontamination objective imposed by the BIM was a concentration of 900 ppm.

From these results it is clear that bioremediation techniques can be efficient on loamy soil on short term, so that further examination for possible bioremediation techniques on finer textures offers quite a lot of perspective.

5. COSTS

The bioremediation technique was also a favourable concept regarding the cost of decontamination. The total cost for bioremediation of the unsaturated area amounted to about 20 million franks. A selective excavation of the contaminated grounds would have easily exceeded a 30 million franks' cost price.

6. PROPOSAL OF A PILOT PROJECT ON BIOREMEDIATION OF LOAMY SOIL

Following the decontamination at the van Oss site, Ecorem proposed to NATO a pilot project, with objective to verify which bioremediation techniques are effective in the decontamination of contaminated loamy soils.

In order to dimension the different technologies to be tested in the scope of this pilot project, the following activities are planned prior to the experimental stage:

- characterisation of the soil to be treated

  This stage consists of the analysis of the soil to be treated, regarding the most relevant organic and inorganic parameters. Therefore, a number of samples will be taken. A good characterisation is necessary because certain pollutants, even in low concentrations, have a certain inhibiting effect on the microbial activity. Complementary to these analyses a certain number of general parameters such as grain size, the C/N relation and the degree of humidity will be determined as well.

- determination of initial microbial activity

  The determination of initial microbial activity is performed based on the classical techniques used in soil microbiology, such as microscopical research (countings), determination of the biomass by fumigation and extraction, respiration measurements (CO_2 production) and ATP determinations.

- Determination of the maximum potential biodegradability of the contamination present

  In order to determine the maximum degradability of the pollutants, column tests with lysimeters are being executed. Therefore optimal conditions for microbial growth and degradation are created by means of addition of water, nutrients, air, microorganisms and other additives. During the column tests the pollutant concentration, the use of oxygen and the CO_2 production are continuously monitored in order to obtain an accurate image of the biodegradability of the pollutants.

The preparatory stages will result in a first indication of the potential applicability of bioremediation as a decontamination technique for loamy soils that were contaminated with hydrocarbons.

Based on the results and conclusions of the preparatory stages a number of decontamination concepts and configurations will be tested on a lab scale. Regarding the in-situ decontamination techniques, this is only executed with the help of column studies based on soil column lysimeters. Regarding the ex-situ decontamination techniques, mainly bioreactor tests will be executed.

Soil column lysimeters are simple but efficient means to verify the possibilities to what extent the soil can be in-situ decontaminated with the help of bioremediation techniques. In **FIGURE 6** a schematic representation of the test setting is given. Different soil columns are being equipped as represented in **FIGURE 6**. In the test setting fluid solutions can be put in with the help of a time-directed system that is established on top of each column. Furthermore, air fumes can be added in each column. Before entering the column, the fumes are lead through a shaft filled with glass pearls to enable a uniform separation. Different column tests will be performed simultaneously to monitor the microbial activity and the evolution of the contaminants under different circumstances and feedings. The liquid solutions will mainly consist of nutrient mixtures containing nitrogen sources, phosphates and oligo-elements. For each column the effluent is collected and analysed on pH, conductivity and nutrient concentrations. In order to measure microbial activity in the column, the production of CO_2 produced is determined. On the columns following treatments will be performed : control setting without specific treatment; only addition of water, addition of water and nutrients, addition of water + nutrients + microorganisms; addition of water + air + nutrients; addition of water + microorganisms + air + nutrients.

Such soil column lysimeters are extremely well equipped to verify whether contaminated sites can be decontaminated in-situ with the help of bioremediation techniques. In addition, the column tests will be used for the evaluation of ex-situ decontamination techniques, during which the contaminated soil will be submitted to different preliminary treatments (e.g. mixing with compost). Different compost formulas and relationships in the process will be tested.

Based on the results of the experiments on a lab scale, the most appropriate concepts will be tested on a larger scale, in order to obtain a more realistic idea. Therefore the ex-situ decontamination techniques will be tested in the soil-recycling centre. Regarding the in-situ decontamination techniques, the different contaminated zones in different sites will be isolated civil-technically in order to prevent a horizontal spreading of the contamination. The volume of isolated cells will amount to approximately $50m^3$. In order to prevent spreading towards the ground water, a pump and injection system are established around different cells. If possible slots will be dug to the depth of 2 to 3 m around the cells. From these slots horizontal perforated tubes will be installed under the cells to enable monitoring of the groundwater as well as of the soil vapour. With this sampling system the heterogeneity of the soil can be optimally studied.

This decontamination experiments will be conducted on the future soil-recycling centre of s.a. Ecoterres in Brussels. This centre will be built on the van Oss site, owned by the G.O.M.B. **FIGURE 7** gives an impression of the future soil-recycling centre.

Figure 1

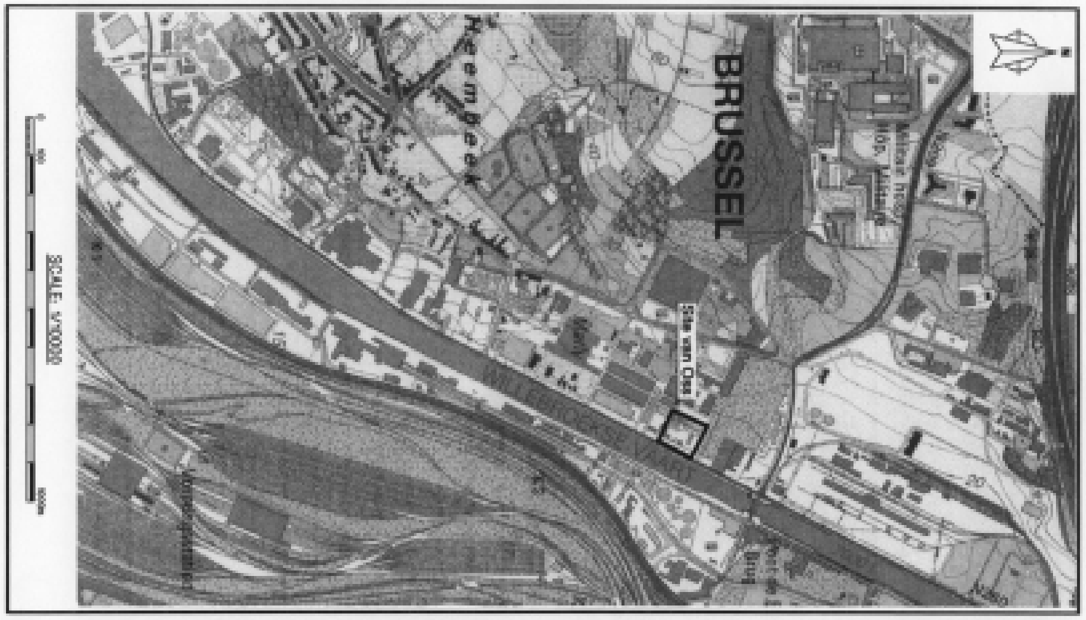


FIG. 1: LOCATION OF "SITE VAN OSS" ON THE TOPOGRAPHICAL MAP

Ecorem

Figure 2

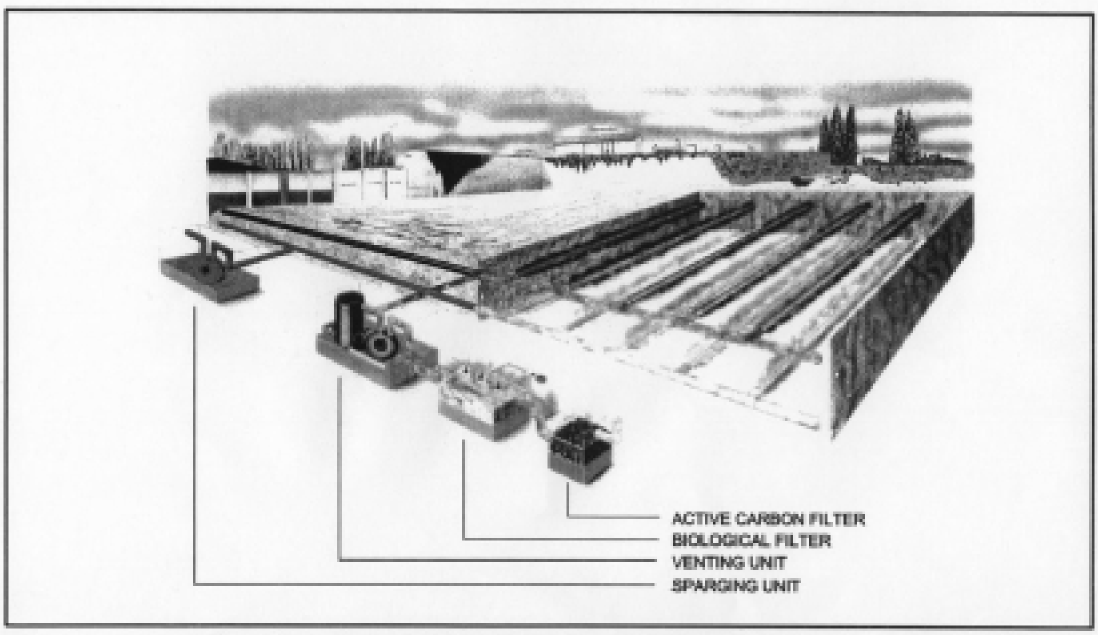


FIG. 2: LAY-OUT OF THE SANITATION ARRANGEMENT

Ecorem

Figure 3

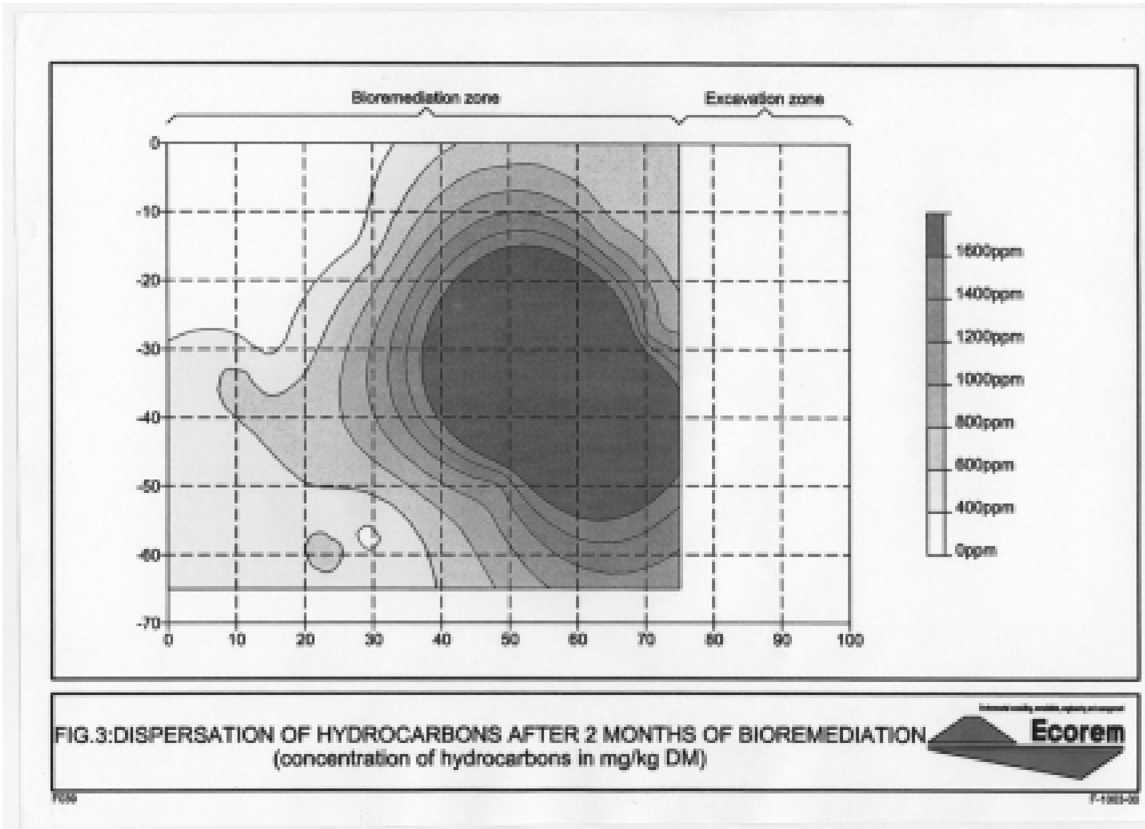


Figure 4

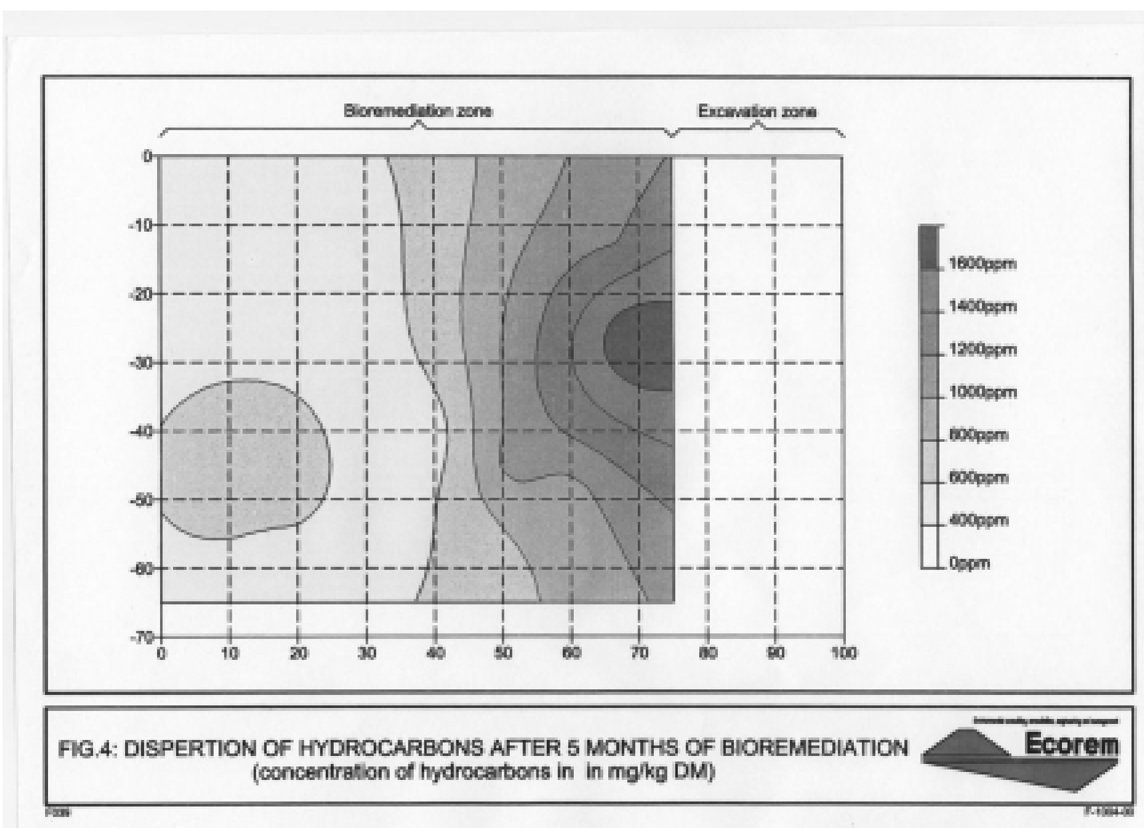


Figure 5

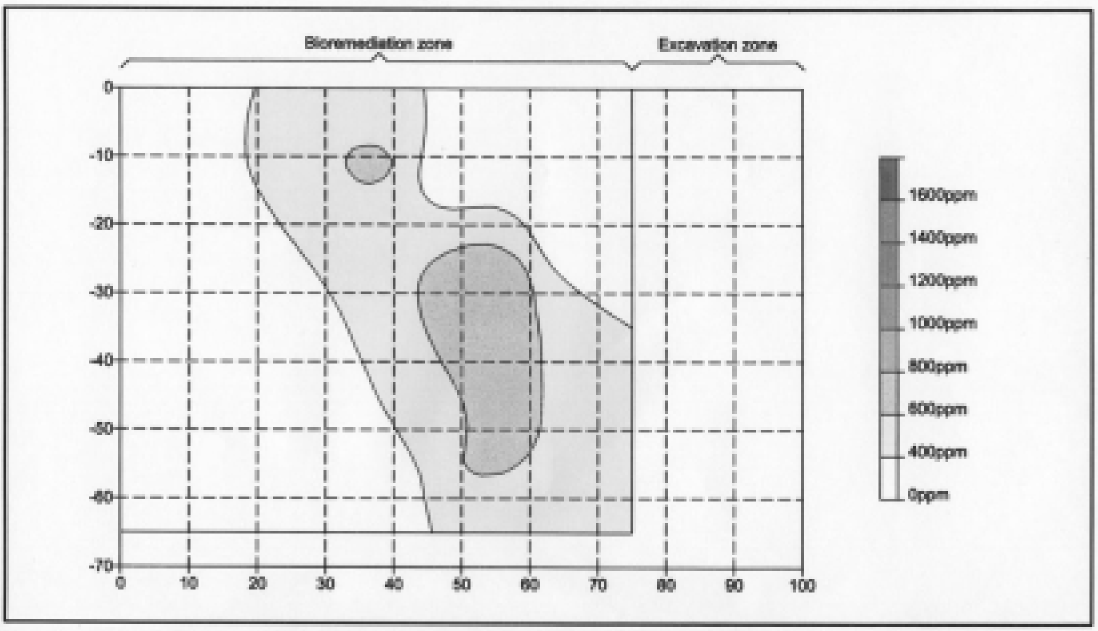


FIG.5: DISPERTATION OF HYDROCARBONS AFTER 10 MONTHS OF BIOREMEDIATION (concentration of hydrocarbons in mg/kg DM)

Figure 6

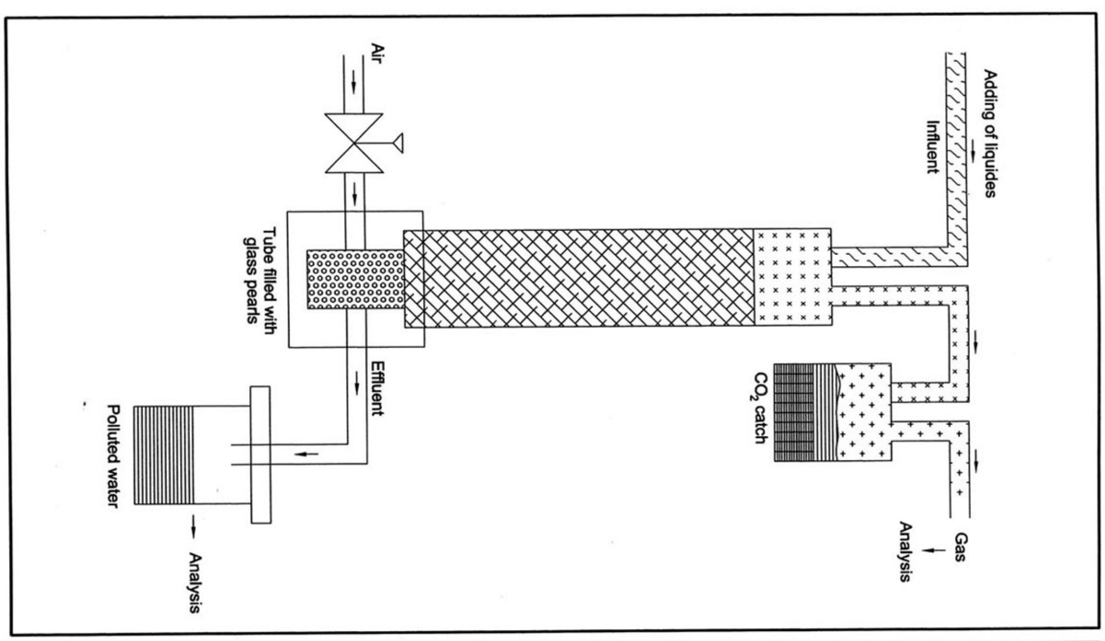


FIG.6: SCHEME OF TESTING LINE-UP

Figure 7

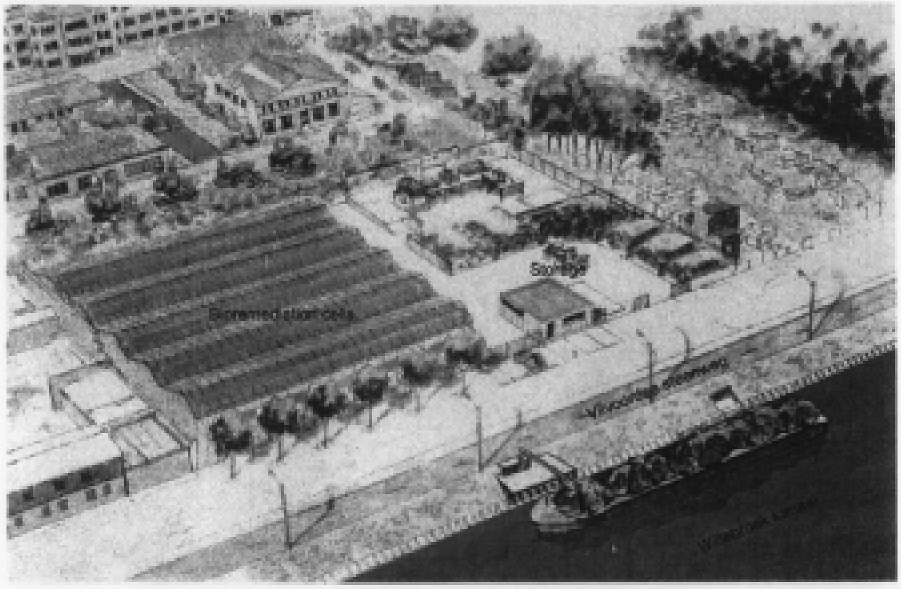


FIG.7: IMPRESSION OF THE FUTURE SOIL REMEDIATION CENTER

Ecorem

Project No. 2			
Pilot Test on Decontamination of Mercury Polluted Soil			
Location Active Chlor-alkali Plant Ústí nad Labem, Czech Rep.	**Project Status** Active Project	**Contaminants** Metallic Mercury	**Technology Type** Gravity Separation
Technical Contact Miroslav Sedlacek Jan Vá• a KAP spol. s r.o. Skokanská 80 169 00 Praha 6 Czech Republic Tel: +420-2-52 74 03	**Project Dates** Accepted 1998 Phase 1 carried out in 1998	**Media** Soil	
Fax: +420-2-57 21 12 55 E-mail: m.sedlacek@prg.kap.cz j.vana@prg.kap.cz	**Costs Documented?** Partly	**Project Size** Semi-operating (up to 5 t)	**Results Available?** Partly

1. INTRODUCTION

This Pilot Test on Decontamination of Mercury Polluted Soil is regarded as a semi-operating demonstration of a progressive and economical technique for on-site cleanup.

2. BACKGROUND

In 1998 an investigation of pollution and risk assessment was completed in the area of plant Spolchemie, a.s., located in the center of Ústí nad Labem in NW Bohemia. High-grade elemental Hg pollution of soil was found in areas adjacent to the former and current buildings of the mercury-cell process for producing caustic soda, caustic potash, hydrogen and chlorine. Maximum concentrations of mercury often reach up to hundreds of thousands ppm. Total amount of Hg is 267 - 445 tons in 222,740 m^3 of polluted soil. The mercury is present in the form of visible drops or softly dispersed in the soil. The scale and character of the pollution has been presented in previous papers in detail. The scale of the cleanup project has not been decided yet but it has been proposed to excavate polluted soil to a depth of 5 m and subsequent decontamination and encapsulation of the lower levels of pollution or monitoring only. A feasibility study evaluating decontamination methods used worldwide was performed. Due to a lack of experience with mercury polluted soil decontamination in the Czech Republic, a Project on Research on Decontamination of Mercury Polluted Soils was elaborated. This project has been divided in two phases – Phase 1 has been focusing on laboratory testing of a gravity centrifugal concentrator (Knelson) and thickening of treated soil. Phase 2 – Pilot Test on Decontamination of Mercury Polluted Soil should test the wet gravity decontamination on a semi-operating scale.

The project is funded completely by National Property Fund of Czech Republic with assumed total cost of 490,000 CZK (17,250 USD).

3. TECHNICAL CONCEPT

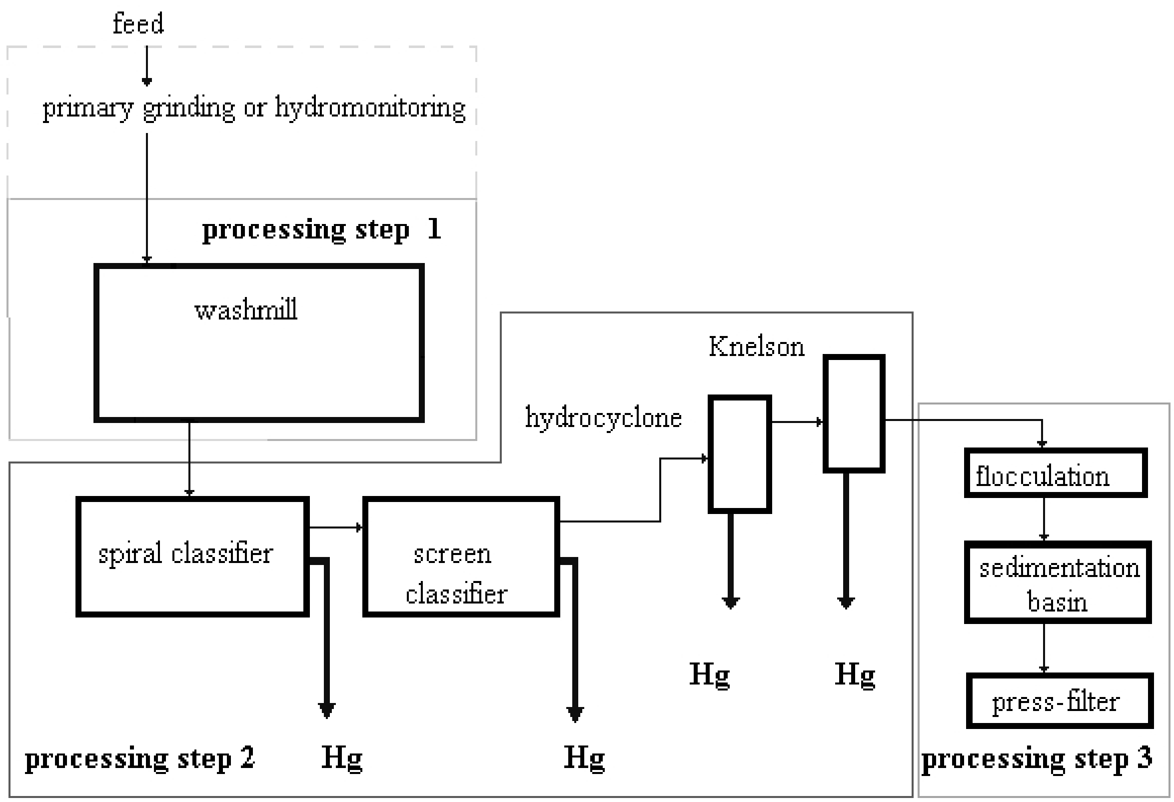
The aim of the Pilot Test is to solve the following problems at a semi-industrial scale:

- to check recovery efficiency of the proposed gravity separation of 1 - 3 m^3 of polluted material;
- to check the influence of possible accompanying pollutants (chlorinated hydrocarbons, heavy metals, chlorides, etc.);
- to check possible adsorption of Hg on clay minerals and its influence on decontamination efficiency;

- to test the de-watering of treated material;
- to specify the energy consumption and total costs of decontamination;
- to design the optimal decontamination unit that could be maintained and operated effectively under the conditions of the local economy and infrastructure; and
- to verify the possibility to utilize the decontaminated material - for example in brickworks.

The proposed decontamination method consists of three main steps: blunging, gravity separation and de-watering as shown in the following scheme. Scheme of proposed decontamination unit:

Processing step 1



Blunging – is a very important operation in the decontamination process - the stage and speed of blunging will have a crucial influence on the success and economy of the process. It is possible that primary raw grinding will be necessary. Roll-breaker or similar equipment can be used. The breaker can be replaced by a hydromonitor with an advantage of drying elimination.

Processing step 2

As the scheme shows, separation of Hg is assumed in several points of decontamination unit. The first separation of mercury will be in a washmill where Hg will be concentrated in coarse fraction. The spiral and screen classifiers should separate the prevailing portion of mercury into coarser fractions – gravel and sand. The clayey suspension will be treated in hydrocyclones and centrifugal separator (Knelson) where the remaining portion of mercury adsorbed on clay should be separated.

Processing step 3

The final step is thickening and de-watering of treated clay. The laboratory tests show that optimal flocculation can be reached by addition of lime water. The flocculant will be dosed continuously and the suspension will be thickened in a sedimentation basin. The thickened suspension will be de-watered in a press-filter. The sedimentation basin overflow water will be recycled in a treatment station. The decontaminated clayey material can be used as backfill, in brickworks, or disposed of on a dump depending on the concentration of pollutants.

Consumption of energy, water, and additional agents will be measured during the Pilot Test as well as other costs - employees, exploitation, processing equipment, waste disposal taxes, etc. The by-products, which may have a positive influence on the economy of decontamination process (Hg, gravel, and clay), will be registered. All the costs connected with the Pilot Test will be recalculated on feed unit.

4. ANALYTICAL APPROACH

Before starting the test the excavated material will be sampled for granularity analyses and RTG analysis to determine the interconnection between mercury and clay particles. During the Pilot Test the feed will be periodically sampled for analyses of Hg or appropriate accompanying pollutants. All the inputs and outputs of individual processing steps will be sampled for Hg analyses both in technological water and separated material.

5. RESULTS

For the time being, only the results of laboratory testing (Phase 1) are available. The laboratory tests demonstrated that the gravity concentration method is suitable for decontamination of Hg polluted soils – in laboratory scale was the concentration 1,150 ppm of Hg (present in visible drops) in polluted reduced to 49 ppm in treated soil.

6. HEALTH AND SAFETY

During excavation, the release of volatile Hg vapors can be high, the workers involved in this operation will be at risk from mercury emissions. Workers will need to be provided where necessary with suitable protective clothing and breathing equipment to protect them from such exposures.

The proposed decontamination method is wet so it is not assumed release of mercury during processing but due to ensuring health protection the workers should use personal protection.

The atmospheric concentrations of Hg vapors would be monitored to ensure the workers' safety during the entire decontamination process.

7. ENVIRONMENTAL IMPACTS

The test will be carried out in the contaminated industrial area of Spolchemie plant. The aim of the proposed work is to improve the current environmental status. The water from processing will be treated in a water treatment station. Other material – i.e. concentrates enriched with separated mercury and treated soil will be used in further tests – recovery of mercury and for verifying the possibility to utilize the decontaminated material (for example in brickworks). All the hazardous remnants will be disposed in accordance with Czech law.

8. COSTS

The total assumed project cost is 17,250 USD, of which 3,000 USD (i.e. approximately 17%) was spent on a Laboratory Test (Phase 1). The anticipated cost of the Pilot Test (Phase 2) is 14,250 USD and its structure is as follows:

- Personnel costs 21%
- Excavation and transport 4%
- Operation 23%
- Sampling and laboratory 33%
- Evaluation 19%

9. CONCLUSIONS

Laboratory tests verified that the gravity concentration method is useful in processing mercury-polluted soil.

The proposed decontamination method, based on the performed laboratory tests, is assumed to be an alternative to expensive thermal decontamination method.

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Project No. 3 **Permeable Treatment Beds**		
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	**Location:** Former solvent blending plant, Essen, Germany	**Project Status:** Interim Report, Field Tests finalized
Media: Groundwater	**Technology Type:** Permeable Reactive Barrier as in-situ groundwater remediation technology	**Project Dates:** Accepted 1997
Costs Documented? No, cost estimation available	**Contaminants:** Chlorinated and nonchlorinated solvents, BTEX-aromates, TCE, PCE	**Project Size:** Full Scale
Results available? No, field test results available		

1. INTRODUCTION

A pilot groundwater treatment plant was installed at a former industrial site in Essen, Germany, where organic solvents had been stored and processed in a small chemical plant for several decades. Leakage and handling losses caused significant soil and groundwater contamination, mainly by BTEX and CHC. The contaminated aquifer has low hydraulic conductivity and is only 2-3 m thick. The aquifer is covered by 4-11 m of thick, silty and clayey covering layers (loess). During investigations and conceptual remediation design, it was determined that the site was suitable to install adsorbent walls since conventional remediation and contamination control measures cannot be applied in a cost-efficient manner.

Subsequently, WCI and IWS studied and reported on various technical variants to install an adsorbent wall in a feasibility study. The study also established which data was necessary to arrive at the dimensions of the adsorbent wall. The feasibility study recommended that pilot tests be conducted on the site for this purpose.

The objective of the pilot tests was to obtain precise information on the adsorption potential for the contaminants at the site, the type and quantity of the required adsorbent material, the functioning of filters at different flow speeds, and the long-term effectiveness as well as the attendant risks, if any, of installing an adsorbent wall.

Conducting the pilot tests involved the following principal tasks:

- Selecting a suitable adsorbent for the tests depending on water quality and the relevant contaminant concentrations at the site;
- Structural design and planning of the pilot plant;
- Operating and taking samples from the pilot plant as well as carrying out laboratory analyses;
- Assessment of the pilot tests.

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, monoethyleneglycol and alcohols were handled stored and processed. Today a residential building is left on the site while underground and above ground tanks are demolished.

The ground was filled up 2,0 m over silty soil (approx. 4 to 11 m thick). Below the silt a layer of sand and gravel (0.8 to 7.4 m) and marly sands (7.0 to 16.3 m below the top) have been detected. The marly sands are the first waterproof layer.

The first aquifer is about 1.0 to 3.2 m thick and the flow velocity is very slow ($k_f = 6.6 \cdot 10^{-6}$ m/s).
The concentrations of main contaminants in groundwater are petrol hydrocarbons 23.6 mg/l to 164.0 mg/l, volatile chlorinated hydrocarbons 27.0 mg/l and aromatic hydrocarbons 153.0 mg/l. Furthermore higher concentrations of manganese and iron are present.

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

3. DESCRIPTION OF THE PROCESS

The pilot plant was fed with groundwater, which was pumped directly from the aquifer into the front column. Two dosing pumps located behind a gravel bed in the front column fed groundwater into columns 1 and 2. The gravel filter served to hold back sediments as well as to eliminate iron and manganese.

- Column 1 contained:
  - 45 cm gravel filter (size: 2 to 3.15 mm)
  - 5 cm activated carbon ROW 0.08 supra
  - 5 cm gravel filter (gravel size: 2 to 3.15 mm)
  - 65 cm activated carbon ROW 0.08 supra

  The thickness of the activated carbon bed in Column 1 corresponded to the recommended thickness of the activated carbon bed of the adsorbent wall in the feasibility study.
- Column 2 contained:
  - 100 cm activated carbon ROW 0.08 supra

  The treated water was led via an overflow into a trough located outside the container.

Groundwater analyses were based on the contamination at the site; their scope was determined by the feasibility study to install an adsorbent wall. The analyses covered field parameters, general parameters and parameters to quantify BTEX and volatile CHC contamination.

The analyzed **general parameters** included sum parameters for organic compounds as well as the parameters iron and manganese. A sum parameter for organic compounds was used in order to study whether it could serve as a substitute for analyses of individual substances. Moreover, the sum parameters were also used to check whether the results of individual analyses were plausible. Iron and manganese contents were determined in order to check whether precipitation of these substances would block the adsorbent wall.

Separate analyses were carried out for BTEX and volatile CHC. The number of analyzed parameters (16) was deliberately large so as to also cover important decomposition products such as vinyl chloride. Contaminant retention by the activated carbon was determined in two ways. Firstly, contaminant concentrations were continuously monitored at the inlet, in the columns and at the column outlets. Secondly, following the conclusion of tests, the columns were disassembled and individual partitions of carbon samples were analyzed for contaminant content. Tests were carried out to determine whether iron and manganese precipitation or microbial activity in the activated carbon could block the adsorbent wall.

Water samples collected on 11 days were tested for numerous parameters; on the whole, over 1,600 individual results were obtained for water samples taken during pilot operation.The determined concentrations for dissolved organic carbons **(DOC)** ranged between 80 and 160 mg/l at the inlet The DOC values correlate well with the CSB and TOC concentrations. No contaminant breakthrough was detected in samples from the outlets of the two columns over a period of almost half a year.

The pilot tests with Columns 1 and 2 confirm that putting up an adsorbent wall is feasible.
With respect to contaminant retention, results of the pilot tests indicate that the long-term effectiveness would be much higher than the estimated period of 30 years in the feasibility study.

4. RESULTS AND EVALUATION

The pilot tests confirm the findings of the feasibility study, to the effect that the site is suited to put up an adsorbent wall. The following statements can be made with respect to the present tests:

- The pilot tests show good **contaminant retention** in the activated carbon, in fact much higher than what was assessed in the feasibility study. Contaminant breakthrough for toluene and trichloroethylene was determined at sampling point S2P50 (i.e. after flow through 50 cm), Column 2, only at the end of the 5-month pilot test operation. By this time, throughput had reached 600 times the bed volume.
- The pilot tests indicate that the **durability** of the wall given a 70 cm-thick activated carbon layer would be much higher than the 30 years estimated in the feasibility study. The thickness of the carbon layer should therefore be reduced when the wall is put up.
- The **DOC concentrations** established during the pilot tests can almost entirely be traced to the contaminants detected at the site. It is therefore to be expected that the adsorbing potential of the activated carbon will not be impaired by natural organic compounds, such as humin.
- Data pertaining to the contaminant breakthrough suggest that the depletion of the adsorbing capacity of the activated carbon is accompanied by a sharp peak in the concentration of volatile substances. A suitable **monitoring system** should therefore be set up when the adsorbent wall is erected.
- The fact that the activated carbon could be **regenerated** after disassembling the plant suggests economic operation of the adsorbent wall.
- Laboratory analyses of the water and activated carbon samples indicate that **iron and manganese precipitation** will be insignificant and will not block the adsorbent wall.
- **Microbial activity** could not be detected in the gravel filter or in the activated carbon; it may be concluded that under the given site conditions, the build-up of bacterial film does not pose a risk.
- **Preliminary laboratory tests** to determine the choice of activated carbon as well as **pilot tests** must be carried out in all cases prior to setting up an adsorbent wall given the variance in site conditions.

5. COSTS

The costs for conducting the field tests have been EURO 50.000,--. The overall costs to erect the wall system and the fill it with activated carbon is estimated to be EURO 750.000,--. Included are additional costs for monitoring the water quality for 30 years, which is a 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% less expensive.

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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
Anthimos Xenidis
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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>

Please note that this project summary was not updated since the 1998 Annual Report. An update will be included in the 2000 Annual Report.

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, © 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 cleander, chemical plant</td><td>Project Status
Intermediate report</td><td>Media
Groundwater</td><td>Technology Type
Biowalls/Bioscreens/ treatment zones</td></tr>
<tr><td rowspan="2">Technical Contact
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S.Staps@mep.tno.nl</td><td>Project Dates
Accepted 1998
Final Report end 1999</td><td colspan="2">Contaminants
Oil, BTEX, Chlorinated solvents, Chlorinated pesticides and benzenes</td></tr>
<tr><td>Costs Documented?
Yes</td><td>Project Size
pilot to full scale</td><td>Results Available
End 1999</td></tr>
</table>

1. INTRODUCTION

Name of the technology: Biowalls/Bioscreens/Biobarrier/Treatment zones

Status of the technology: bench, pilot to full scale; emerging and innovative

Project objectives: 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) is contaminated with perchloroethylene (PCE) and trichlorethylene (TCE). It concerns an unconfined aquifer with a clay aquitard at a depth of 9 m. The plume is located at a depth of 6 - 9 m and 150 m long and 30 to 60 m wide, and has mixed redox conditions, i.e. separate reducing and oxidising zones. Transformation rates of especially vinylchloride as observed in the field (and in the laboratory) are too slow to prevent migration of this hazardous compound to areas to be protected. Source remediation and plume interception are therefore required.

Oil refinery site. At this site in the Rotterdam Harbour 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). Natural degradation of all HCH-isomers was demonstrated at the site of investigation. Interception of the HCH/Chlorobenzene/benzene plume is needed to protect a canal located at the boundary of the site.

3. DESCRIPTION OF PROCESS

Chlorinated solvent site. Laboratory experiments identified that a mixture of electron-donors is most suitable to enhance the in situ reductive dechlorination. In situ full-scale demonstration of enhanced anaerobic degradation in the source zone designed for complete reductive dechlorination is currently performed. The same technology is considered to be applied later at the head of the plume in terms of a treatment zone.

Oil refinery site. Bench scale experiments have been finished and established i) optimal grain-size and packing density for the porous media used in the trench, ii) optimal oxygen supply rates to sufficiently initiate aliphatic hydrocarbon biodegradation and to minimise clogging with iron (III) oxides. Three different technologies are being tested at pilot scale: two gravel filled reactive trenches with biosparging units and one biosparging fence, without excavation of the soil. Each pilot application has a length of 40 m, and a depth of 4 meters.

Aromatic hydrocarbon (BTEX) sites. Microcoms were used to investigate possibilities to stimulate biodegradation of benzene and TEX 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. Pilot demonstration tests are currently performed. One pilot test is a biostimulated zone with dimensions of 10 to 10 meters.

Chlorinated pesticide site. A bioactivated zone as an alternative to conventional large-scale pump-and-treat is currently being investigated. Laboratory process research indicated that a combination of anaerobic-microaerophilic in-situ stimulation in a bioactivated zone is the most feasible approach. Preparations are being made to incorporate the installation of the biotreatment zone in new building activities ate the site.

4. RESULTS AND EVALUATION

The status of most projects is that they recently have entered a pilot or a full-scale phase. First evaluations of technology performance are to be expected at the end of 1999.

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 indicate that biotreatment zones are in most cases the cheapest and most flexible approach, whereas funnel-and-gate™ systems and reactive trenches have a cost level comparable to conventional pump-and-treat. Biotreatment zones have therefore the greatest market perspective, whereas funnel-and-gate™ systems and reactive trenches can be used when a high degree of protection is required or when these approaches can be integrated with other building activities planned at the site.

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Project No. 6

Rehabilitation 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

Please note that this project summary was not updated since the 1998 Annual Report. An update will be included in the 2000 Annual Report.

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

Project No. 7 **Risk Assessment for a Diesel-Fuel Contaminated Aquifer Based on Mass Flow Analysis During Site Remediation**			
Location Menziken/Studen, Switzerland	**Project Status** Interim	**Media** Groundwater	**Technology Type** In situ Bioremediation
Technical Contact Mathias Schluep BMG Engineering AG Ifangstrasse 11 8057 Schlieren Switzerland Tel: +41/1-732-9286 Fax: +41/1-730-6622	**Project Dates** Accepted 1997 Final Report 2000	**Contaminants** Petroleum Hydrocarbons (Diesel Fuel, Heating Oil)	
E-mail: mathias.schluep@bmgeng.ch	**Costs Documented?** No	**Project Size**	**Results Available?** Yes

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. 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* [1] 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* [2] 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

Emphasis was put into the assessment of processes controlling the risk development at petroleum contaminated sites. Laboratory studies were performed to study the dissolution of aromatic hydrocarbons from diesel fuel into the aqueous phase and the biodegradation of the soluble fraction of diesel fuel under denitrifying and aerobic conditions. Results of the research could be applied successfully to perform a risk assessment at the Menziken [3] and the Studen site [4].

4. RESULTS AND EVALUATION

In laboratory systems it could be shown that Raoult's law is valid during dynamic dissolution of aromatic compounds from complex NAPL mixtures (e.g. diesel fuel, heating oil) in non-disperse liquid/liquid systems. This is true as long as a significant depletion of substances is observable. At low NAPL concentrations non-equilibrium effects probably play a major role in the dissolution behavior. The quality of predictions could be improved by considering time varying NAPL mass. Results will be published in fall '99 [5].

In column studies the potential of PHC mineralization under denitrifying and aerobic conditions could be evaluated for selected aromatic substances. Results are subject of further evaluations and a basis for other studies. Publications are scheduled for early 2000.

The risk in Menziken and Studen could be assessed with two diploma thesis's [3, 4] based on the studies which were performed in the laboratory [5] and the field [1, 2]. Mass balance calculations were used to characterize the field sites concerning the present risk, the risk development, and the site's potential to remove PHC due to biodegradation processes. Generally it is assumed that those calculations allow to plan initial remedial action and a long term remedial strategy at PHC contaminated sites. It is also assumed that the risk development is predictable during site remediation within acceptable uncertainty ranges. Publications are scheduled for early 2000.

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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	**Project Status**	**Contaminants**	**Technology Type**
Istanbul University	Interim Report	Heavy metals (Pb, Cu, Cd) and radionuclides (^{137}Cs, ^{90}Sr, ^{238}U), textile dyes	*In situ* adsorption and stabilization/ solidification
Technical Contact	**Project Dates**	**Media**	
Resat Apak Istanbul University Avcilar Campus, Avcilar 34850 Istanbul, Turkey tel: 90/212-591-1996 fax: 90/212-591-1997 e-mail: rapak@istanbul.edu.tr	Accepted 1998 Interim Report 1999 Final Report 2000	Soil and groundwater (Unconventional sorbents e.g., red muds and fly ashes simulate hydrous oxide-like soil minerals; kaolinite and feldspar represent clay minerals)	
	Costs Documented?	**Project Size**	**Results Available?**
	No	Bench-scale	Partly yes

1. INTRODUCTION

When a spill or leakage of a heavy metal/radionuclide contaminant occurs, *in situ* soil and groundwater technologies are generally preferred to cope with the contaminants and to prevent their dispersion outside the site. Barrier wall technologies employ immediate action that restricts the expansion of the contaminant plume. Thus, this project involves a laboratory-scale investigation of the use of metallurgical solid wastes and clay minerals as barrier materials to adsorb toxic heavy metals and radionuclides from water (a fixation or stabilization process) followed by solidification of the metal-loaded mass in a cement-based block totally resistant to atmospheric weathering and leaching conditions.

2. BACKGROUND

Metals account for much of the contamination found at hazardous waste sites. They are present in the soil and groundwater (at approximately 65% of U.S. Superfund sites) coming from various metal processing industrial effluents. Turkey also has metal (Pb, Cd, Cu, Cr, U etc.) contaminated sites due to effluents predominantly from battery, electroplating, metal finishing and leather tanning industries, and mining operations.

Cesium-137 and strontium-90, with half-lives of 30 and 28 year, respectively, pose significant threats to the environment as a result of fallout mainly from power plant accidents. In Turkey, ^{137}Cs became a matter of public concern after the Chernobyl accident, especially contaminating the tea plant harvested in the Black Sea Coast of the country. On the other hand, milk products and other biological materials containing Ca were extensively investigated for possible ^{90}Sr contamination. Land burial of low-level radioactive wastes also pose a contamination risk to groundwater.

Physical/chemical treatment processes specific to metals/radionuclides include chemical precipitation, ion exchange, electrokinetic technologies, soil washing, sludge leaching, membrane processes and common adsorption. When adsorption is employed, there is an increasing trend toward substitution of pure adsorbents (e.g., activated carbon, alumina and other hydrated oxides) with natural by-products, soil minerals or stabilized solid waste materials (e.g., bauxite waste red muds and fly ashes). These substances also serve as barrier material for passive wall technologies utilized around a heavy metal spill site or shallow-land burial facility of low-level radioactive wastes. Once these contaminants are stabilized within barrier walls, it is also desirable to fix them in an environmentally safe form by performing *in situ* stabilization/solidification by way of adding cement - and pozzolans if necessary – to obtain a durable concrete mass. The host matrix for metals and radionuclides, i.e., red muds, fly ashes and clay minerals, may serve as inexpensive pozzolanic binders to be used along with cement for solidification.

The aim of this Pilot Study project is to develop unconventional cost-effective sorbents for basically irreversible fixation of heavy metals/radionuclides; these sorbents should show high capacities and fast retention kinetics for the so-called contaminants. The determination of conditions affecting stabilization/solidification of the loaded sorbents by adding pozzolans and cement is also aimed. Durability and leachability of the final concrete blocks have to be tested. Modeling of sorption of heavy metals/radionuclides onto the tested materials has to be made in order to extend the gained knowledge to unforeseen cases. Finally a reasonable unification of *in situ* physical/chemical treatment technologies applicable to a spill/leakage site will be accomplished.

3. TECHNICAL CONCEPT

The effect of various parameters (sorbent grain size, pH, time of contact, contaminant concentration, metal speciation etc.) affecting the adsorption/desorption behavior of the selected heavy metals onto/from the sorbents has been investigated. The sorption capacity (batchwise and dynamic column capacities)and leachability of the sorbents in terms of heavy metals/radionuclides have been estimated by the aid of batch contact, column elution and standard leaching (simulating groundwater conditions) tests. Possible interferents (e.g., inert electrolytes as neutral salts) have been incorporated in the synthetic contaminant solutions so as to observe any incomplete adsorption or migration of contaminants that may occur under actual field conditions. The sorption data have been analyzed and fitted to linearized adsorption isotherms. New mathematical models have been developed to interpret equilibrium adsorption data with simple polynomial equations.

Red muds and fly ashes, after being loaded to saturation with Pb(II), Cd(II) and Cu(II), were solidified to concrete blocks which should not pose a risk to the environment. The setting and hardening characteristics of mortars as well as the flexural and mechanical strengths of the solidified specimens were optimized with respect to the dosage of natural and metal-loaded solid wastes. Extended metal leaching tests were carried out on the solidified samples.

These treatment steps actually serve the perspective of unification of seemingly separate physical/chemical technologies for the removal of heavy metals/radionuclides in environmentally safe forms. The developed barrier materials in a way resembles iron hydroxides and oxyhydroxides that are currently developed from low-cost iron waste streams by DuPont (Hapka, 1995). In the meantime, although not directly fitting with the project title, the usage of iron fillings as potential barrier material has been tested for the management of textile dyeing wastes, e.g., as a restricting agent for an uncontrolled expanding plume from a permeable storage lagoon or pond where textile wastes are collected.

4. ANALYTICAL APPROACH

The metallurgical solid wastes used as sorbents were supplied from Turkish aluminium and thermal (coal-fired) power plants, and characterized by both wet chemical and X-ray (diffraction and fluorescence) analysis. They were subjected to chemical treatment (water and acid washing) for stabilization, and classified with respect to size when necessary. Their surface areas were determined by BET/N_2 surface area analysis, and their surface acidity constants (pK_a) by potentiometric titration.

After equilibrating the sorbents with the metal solutions, all metal determinations in the centrifugates were made with flame atomic absorption spectrometry (AAS) using a Varian SpectrAA FS-220 instrument. The beta activities of the Cs-137 and Sr-90 radioisotope containing centrifugates were counted by a ERD Mullard Geiger Muller tube type MX 123 system with halogen extinction. The batch and dynamic adsorption and desorption tests were carried out in thermostatic shakers and standard pyrex glass columns, respectively.

A mortar-mixing mechanical apparatus, ASTM Vicat apparatus, steel specimen moulds (4x4x16 cm^3), tamping-vibrating apparatus, and testing equipment for flexural and compressive strength tests were used for following the solidification process and the mechanical strength of the final concrete blocks.

The textile dyes used for modeling textile wastes were analyzed by UV/Visible spectrophotometry.

The adsorption isotherms conforming to Langmuir, Freundlich, B.E.T. and Frumkin isotherm equations were evaluated by linear regression and non-linear curve fitting of experimental data.

5. RESULTS

The distribution coefficients of metals (as Log K_D) between the solid (red mud, fly ash etc.) and solution phases varied between 1-3 and showed a gradual decrease with increasing equilibrium concentration of the metal remaining in solution.

The Langmuir saturation capacities of the sorbents (in the units of mg metal per g sorbent as red mud-fly ash, in this order) for the metals averaged at approximately 50-200 mg $Cd.g^{-1}$, 40-100 mg $Cu.g^{-1}$, and 100-350 mg $Pb.g^{-1}$.

The adsorption isotherms were somewhat S-shaped B.E.T. type isotherms showing layered sorption at the natural pH of equilibration, but saturation of the sorbent was attained at a definite concentration enabling an approximated Langmuir evaluation of equilibrium data in operational sense.

The order of hydrolysable divalent metal cation retention on the selected sorbents were as follows in terms of molar saturation capacities: Cu > Pb > Cd for fly ashes and Cu > Cd > Pb for red muds. The degree of insolubility of the metal hydroxides approximately followed the same order. The simulation of CO_2-injected groundwater conditions were achieved by saturated aqueous CO_2 (pH 4.8) and carbonic acid/bicarbonate buffer (pH 7.0) solutions. The heavy metals (Cu, Pb, Cd) retained on the sorbents were not leached out by these carbonated leachant solutions.

Heavy metal adsorption onto red muds, either as free metal ion or in chelated metal-EDTA forms, has been effectively modeled for (M+M-EDTA) mixtures. The adsorption data could be theoretically generated by using simple quadratic equations in terms of covalently- and ionically- adsorbed metal concentrations in the sorbent phase, once the total metal concentration prior to equilibration and final solution pH were known.

As for solidification of the metal-loaded solid wastes, when these loaded wastes were added up to 20% by mass to Portland cement-based formulations, the fixed metals did not leach out from the solidifed concrete blocks over extended periods, with the exception of Cu(II), which reached a concentration of 0.4 ppm after 8 months in a water leachate of pH 8-9. 2% setting accelerator $Ca_3(PO_4)_2$-added improved formulations could bear only 10% of lead-loaded fly ash, while this tolerance could be raised to 20% fly ash by incorporating (3% $Ca_3(PO_4)_2$+1% $CaCl_2$) mixed additive.

The studied radionuclides did not show a significant temperature dependency in adsorption. Especially radiostrontium retention increased with pH. These observations are in accord with ion exchange mechanism of sorption. Radiocesium adsorption is maximal around neutral pH which is specific for most natural waters.

Of the textile dyes tested, acid blue and acid yellow showed 75-90% and 60-80% removal, respectively, when passed through a granular iron bed at an initial concentration of 10-100 ppm dye containing 0.10 M HCl in solution.

6. HEALTH AND SAFETY

The primary components of the unconventional sorbent suspensions, i.e., red muds and fly ashes containing Fe_2O_3, Al_2O_3, SiO_2, TiO_2 and some aluminosilicates, to be used as barrier material are essentially non-toxic. The tested heavy metals, either as free ions or in chelated forms, i.e., Cd^{2+}, Pb^{2+} (and partly Cu^{2+}) and Cd-$EDTA^{2-}$, Pb-$EDTA^{2-}$, Cu-$EDTA^{2-}$, were toxic, so care should be exercised especially in solidification/ stabilization processes using the heavy metal-loaded sorbents in dry form where small particles could be inhaled by workers. Also working with radionuclide solutions, even in very dilute forms, needs special pipettes and glassware to be used under a hood on a stainless steel work-bench, and special laboratory practice with workers wearing radiation dosimeters. All waste solutions even at very low-level activity should be properly collected and submitted to the nuclear energy authority for waste storage and stabilization.

7. ENVIRONMENTAL IMPACTS

Prior acid or water leaching of the sorbents before adsorption experiments did not effectively increase the specific surface area or chemical adsorption power of these sorbents, but rather these sorbents were stabilized so as not to leach out any micropollutants to water at the time of heavy metal adsorption. It is also indicated in literature that iron oxyhydroxide based grouts as barrier material can be made from low cost industrial by-products, which should be tested for safety and effectiveness on a case-by-case basis (Hapka et al., 1995). Thus these criteria should be judged for red muds and fly ashes.

Stabilization/solidification of the metal-loaded solid wastes puts these wastes and incorporated toxic metals into environmentally safe (mechanically strong, durable and unleachable) forms. The matrix disrupting effect of Pb was eliminated by using relatively small amounts of sodium aluminate or calcium phosphate to improve the setting, hardening and mechanical properties of the final concrete blocks. It was environmentally safe to observe that the matrix-held metals (either as a result of irreversible adsorption or solidification) did not leach out by carbonate or carbonic acid solutions ensuring the chemical stability of these solid wastes under changing groundwater conditions.

8. COSTS

Because iron-based grouts (without relatively expensive additives such as citric acid, urea and urease) can be prepared from inexpensive by-products, the primary costs involved come from transportation and additives (Jet grouted, 25% grout) roughly around 50 USD per m^2 for 1m thick wall, i.e., or 50 USD for 1 cubic meter. The overall cost data have not yet been obtained.

9. CONCLUSIONS

In investigation of the possibility of usage of metallurgical solid wastes as cost-effective sorbents in heavy metal (Pb, Cu, Cd) and radionuclide (Cs-137 and Sr-90) removal from contaminated water, red muds and especially fly ashes have been shown to exhibit a high capacity. Extensive modeling of heavy metal sorption – either as free metal ions or in the form of EDTA-chelates – has been performed by simple quadratic equations in terms of the retained metal concentration in the sorbent phase. These modeling efforts enable to predict heavy metal adsorption in different media over a wide pH and concentration range. The developed iron- and aluminium- oxide based sorbents may be used as barrier material as cost-effective grout for the prevention of expansion of a heavy metal contaminant plume.

Heavy metal-loaded solid wastes have been effectively solidified by adding cement, sand and water. The setting and mechanical properties of concrete specimens obtained by optimal dosage of waste addition were satisfactory. The fixed heavy metals did not leach out appreciably into water over extended periods.

The usage of iron fillings as potential barrier material has been successfully tested for the management of textile dyeing wastes, i.e., acid blue and acid yellow.

A unified passive technological process for the *in situ* sorption of heavy metals, radionuclides and textile wastes using iron oxide-, alumina- and silica- based metallurgical solid wastes functioning as barrier material in conjunction with granular metallic iron is on the way of development. The presumed process is planned to be finished with *in situ* stabilization/solidification.

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<table>
<tr><td colspan="4">Project No. 9
Solidification/Stabilization of Hazardous Wastes</td></tr>
<tr><td>Location
Middle East Technical University, Ankara, Turkey</td><td>Project Status
Initial Project Description</td><td>Media
Soil and solid wastes from mining and paper and pulp industries</td><td>Technology Type
Solidification/ Stabilization</td></tr>
<tr><td rowspan="2">Technical Contact
Kahraman Ünlü
Middle East Technical University
Environmental Engineering Dept.
06531 Ankara, Turkey
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E-mail: kunlu@rorqual.cc.metu.edu.tr</td><td>Project Dates
Accepted 1998
Final Report 2000</td><td colspan="2">Contaminants
PCBs, AOX (adsorbable organic halides), heavy metals</td></tr>
<tr><td>Costs Documented?
No</td><td>Project Size
Bench Scale</td><td>Results Available?
Partially yes</td></tr>
</table>

1. INTRODUCTION

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 *(i)* to investigate the effectiveness and reliability of the S/S technology for the safe disposal of hazardous wastes containing metal and organic contaminants, *(ii)* to determine the appropriate technical criteria for applications based on the type and composition of hazardous wastes, and *(iii)* to determine the unit costs associated with the field scale applications of the S/S technology.

2. BACKGROUND

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 to be generated in the future, but also concerns with the existing hazardous wastes and their safe disposal in compliance with the current regulation. The 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.

3. TECHNICAL CONCEPT

The following technical criteria are 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 via conducting comprehensive strength tests on and measuring microstructural characteristics of solidified samples. In this study, for metals a residue material from gold mining, for organics PCB contaminated soil and AOX containing sludge or wastewater from paper and pulp industry will be used. 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 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.

4. ANALYTICAL APPROACH

In this project, for mining residue and PCB-contaminated soil materials, two samples representing fine, and coarse particle size distribution will be prepared (total four samples). And for each waste material representing a given particle size distribution class, two different portland cement mixing ratio will be used. These ratios will be as follows: for metal contaminants (mining waste) 10 and 20%; 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 10 waste samples prepared in this manner will be cured nearly twenty eight 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, on the same solidified waste samples standard TCLP tests of U.S. EPA will be performed. The same leaching tests will also be performed on unsolidified samples. On the leachate, pH and concentrations of the following contaminants will be measured: Cd, Cr, Cu, Fe, Pb, Zn, Ca, Mg, Na, K, Cl, SO_4, HCO_3, 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.

5. RESULTS

Initial chemical and TCLP analyses on gold mining residue material showed that heavy metal (Cd, Cr, Cu, Pb, and Zn) concentrations are too low to classify the residue material as hazardous waste. Therefore a synthetic waste is prepared by adding metal salts to the gold mining residue. The final metal concentrations in the synthetic waste was set to be 1000 mg/kg for Cd, Cr, Cu, Pb, and Zn.

So far unconfined compressive strength and hydraulic conductivity tests have been performed on duplicate samples of mining waste with fine particle size distribution mixed and cured with 10% portland cement. Before conducting these tests, additional tests were also performed to determine some physical and the rheological characteristics of waste:cement mixture. Particle size distribution analysis for the "*fine*" waste sample mixed with 10 % portland cement yielded 25 % fine sand, 55 % silt and 20 % clay. This sample has a specific gravity of 2.72 and a pH of 11. The compaction tests performed to determine the maximum dry density and optimum moisture content yielded a maximum dry density value of 1.8 g/cm^3 with optimum moisture content of 15 %. The samples used for comprehensive strength and hydraulic conductivity tests after 28-day curing were prepared by compacting the waste:cement mixture at 15 % moisture content to a density of 1.8 g/cm^3. Rheological tests yielded liquid limit value of 28 %, plastic limit value of 18 % and plasticity index value of 10 %. The unconfined compressive strength tests were performed using triaxial shear apparatus. The average of duplicate samples yielded an unconfined compressive strength value of 1153 kPa. Compared with the comprehensive strength value of 16 MP for ordinary concrete, this seems to be small. Saturated hydraulic conductivities of solidified duplicate samples were measured using a flexible wall permeameter, and the average value determined to be 1.8×10^{-9} m/s. Leaching and micro-structural tests for this set of samples and other aspects of the project are currently under way.

6. HEALTH AND SAFETY

Not available.

7. ENVIRONMENTAL IMPACTS

Not applicable.

8. COSTS

Not available.

9.CONCLUSIONS

At this stage of the project, the available data are not sufficient to draw any meaningful conclusions.

10. REFERENCES

None.

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

Metal-biofilm Interactions in Sulphate Reducing Bacterial Systems</td></tr>
<tr><td>Location
Under development in consortium's laboratories</td><td>Project Status
Final Report</td><td>Contaminants
Metals</td><td>Technology Type
Biological Treatment</td></tr>
<tr><td rowspan="2">Technical Contact
Prof. Harry Eccles
BNFL,
Research & Technology,
Springfields,
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Tell 44 1772 762566
Fax 44 1772 762891
E-mail he1@bnfl.com</td><td>Project Dates
Project accepted 1998
Final project report 1999</td><td colspan="2">Media
Effluents/Ground water</td></tr>
<tr><td>Costs Documented?
No</td><td>Project Size
Laboratory</td><td>Results Available?
Yes</td></tr>
</table>

1. INTRODUCTION

The development of Sulphate Reducing Bacteria to remove toxic heavy metals and radionuclides from liquid effluents and/or contaminated ground waters. The technology is currently at the laboratory scale to provide fundamental data to enable engineers to design better bioreactors. SRB technology for the removal of toxic heavy metals has been used on a limited number of occasions. In general the bioreactors have been over-engineered thus increasing both the capital and operational costs and consequently the technology is not perceived as competitive. With intrinsic bioremediation, under anaerobic conditions, such as wetlands technology, SRB plays a key 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 aim of this project was to generate new fundamental data by:

- Employing a purpose designed biocell
- Generating fundamental metal precipitation data from this biocell
- Investigating factors affecting growth of sulphate-reducing bacterial (SRB) biofilms
- Quantification of important biofilm parameters on metal immobilisation

2. SITE DESCRIPTION

The studies were carried out in the consortium's laboratories.

3. DESCRIPTION OF THE PROCESS

Biological processes for the removal of toxic heavy metals are presently less favoured than their chemical / 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 used a novel biofilm reactor to provide such information that 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 sulphate ions in liquid waste streams to hydrogen sulphide, which with many toxic heavy metals will precipitate them from solution as their insoluble sulphides.

As the solubility products of these sulphides are very small the final treated effluent will meet the most stringent specification. Equally as the biological system is an active metabolic one the initial metal concentrations can be comparatively high i.e. a few hundred ppm.

The project commenced on the 1 April 1996 and was completed on the 31 March 1999.

4. RESULTS AND EVALUATION

At the outset of this project it was appreciated that consistent, reproducible transferable results were required from both of the laboratories (Westlakes Scientific Consulting [WSC] and the University of Dundee [UOD]) involved in the project. Equally biofilm characterisation protocols needed to be developed/modified so that the SRB biofilms grown under a variety of conditions and challenged with several toxic heavy metals could be comprehensively examined.

1. Biocell Design and Operation

A key component of the project was the provision of sound laboratory data in reasonable time-frames. To satisfy these and other criteria a purpose designed biocell was constructed by a local specialist engineering company. Prior to manufacture the design of the biocell with respect to flow regimes for a variety of liquor flow-rates was simulated using CFD and subsequently verified by both WSC and UOD. Laminar flow was achieved throughout (>95%) of the biocell biofilm active region.

The biocell comprised of two chambers separated by a membrane. In some experiments a porous membrane was employed thus allowing a variety of experiments to be carried out which included for example:

- The separation of carbon source, or sulphate or heavy metal from the SRB biofilm.
- Transfer, by pressure manipulation, of carbon source, or sulphate through the membrane into the biofilm with the generated sulphide subsequently coming into contact with the metal solution.
- The reverse of the above.

The biocell units were constructed in two sizes (lengths), a larger one (500 mm biofilm active length) and a smaller unit (100 mm biofilm active length). The longer biocell was largely used for growing the initial SRB biofilm on an appropriate membrane and dissected into lengths that could be accommodated by the smaller unit. Most of the metal precipitation studies were undertaken in these units.

The philosophy for this arrangement was the period for biofilm growth was not less than 14 days whereas metal precipitation studies took no more than 2 days to complete.

2. Factors affecting biofilm growth

A major variable was the identity of the carbon/energy source used for culture. In general sulphate reduced per mol of carbon source consumed was in the order: lactate > ethanol > acetate. Organic nitrogen (e.g. a defined vitamin solution) also stimulated yield. However, a complex organic nitrogen source e.g. yeast extract did not further stimulate yield. The structure of the support material also affected biomass yield. Pore size stimulated yield between pore sizes of 20-100 μm. This appeared to primarily affect the area available for attachment.

Temperature (maximum growth at 30°C), and the substrate concentration also affected growth and sulphate reduction significantly and K_m values were determined. No effect was observed due to phosphate concentration, inorganic N concentration or support material or hydrophobicity. Prolonged culture led to deeper biofilms but the maximum active depth (shown by fluorescein diacetate-staining) remained at approximately 500 μm with deeper material appearing to be inactive.

2.1 Substrate Utilisation

The biofilm flow cell (biocell) was a key element in this project. It allowed a defined area of biofilm to be incubated under defined conditions of rheology and nutrient supply by recirculating medium from a reservoir and samples of the recirculating medium can be removed for assay. Substrate-utilisation was studied in the biocell as a closed system where a fixed quantity of medium was circulated and the substrate was depleted over time by the metabolic activities of the biofilm.

This system permitted measurement of the concentration and rate of use of substrates. Sodium lactate was rapidly utilised, producing acetate. Varying the concentrations over a 10- to 20-fold range and allowed determination of lactate utilisation kinetics, which was carried out by personnel engaged on process modeling (K_m @ 1,4 mM). Acetate was utilised very slowly by the biofilm culture and accumulated during experiments on lactate utilisation as it was produced by SRB metabolising lactate.

When acetate was supplied as the sole carbon/energy source, its rate of utilisation and the accompanying sulphate reduction were almost undetectable so that no kinetic parameters could be determined. The low acetate utilisation appeared to result from absence of acetate-degrading organisms from the mixed culture, probably as a result of selection by maintaining the culture on lactate as sole carbon/energy source. An acetate-utilising mixed SRB culture was obtained, combined with the lactate-utilising culture and the combined culture was maintained on mixed lactate and acetate as carbon/energy source. This combined culture utilised acetate considerably faster than the lactate-grown culture alone. However, it was not possible to fit a single set of kinetic parameters to the data.

As the addition of an acetate-utilising culture led to increased acetate utilisation, it appears that the very low rate of acetate utilisation in the original culture was due to the absence of acetate-degrading organisms.

2.2 Effects of metal uptake on biofilm growth

Biofilms exposed to Cd or Cu in the growth medium accumulated the metal sulphides. Metal sulphide uptake was accompanied by increased content of protein and polysaccharide content of the biofilm as well as its increased thickness. The increase in polysaccharide was considerably greater than of protein, so that it appeared that extracellular polysaccharide was secreted in response to the accumulation of metal sulphides in the biofilm. The accumulated metal sulphides were concentrated in the upper part of the biofilm and resulted in increased biofilm thickness, but the depth of active (fluorescein diacetate-staining) biofilm remained the same (approximately 500 µm) in metal-loaded biofilms**.** Metal sulphide deposits could, however, overlie the active cells in metal-loaded biofilms, which indicates that these deposits did not obstruct diffusion of nutrients to the biofilm.

3. Metal Precipitation studies

3.1 Metal (Cd and Cu) bioprecipitation

The kinetics and metal mass-balances of Cd and Cu bioprecipitation were studied using the biocell system. After flushing sulphide from the system, the appearance of soluble sulphide in the medium was rapid in the absence of metals but was delayed, in the presence of Cd or Cu. The apparent "shortfall" of sulphide was stoichiometric with the metal added to the medium, which was consistent with metal sulphide formation. However, not all of the metal sulphide formed was immediately precipitated, as some remained dispersed as colloidal material. A method of fractionating the metal into soluble, colloidal and precipitated fractions was developed and the time-course of formation and transformation of these fractions was investigated, this indicated that colloid flocculation to form precipitated solids was relatively slow compared to sulphide formation and appeared to be rate-limiting for the overall bioprecipitation process**.** Data on sulphate reduction, sulphide formation and colloid flocculation was used to parameterise and test a mathematical model that confirmed the rate-limiting nature of the flocculation step. In continuous culture, with a hydraulic residence time of 5 h, both Cd and Cu were precipitated. At metal concentrations used in batch experiments (250 µM), almost all metal was precipitated with a small colloidal phase and almost no remaining dissolved metal At 500 and 1000 μM metal a similar result was observed but with more of the metal remaining in solution and a similar percentage (approximately 5-10%) in the colloidal phase. It therefore appeared that the processes occurring in a continuous culture system were similar to those occurring in batch culture and that the residence time allowed significant flocculation of the colloidal material to take place. Although it is clearly an important component, the occurrence of a significant colloidal phase in metal sulphide bioprecipitation is a novel observation that does not appear to have been previously reported.

3.2 Iron precipitation

The degree of iron sulphide formation by the biofilm (not previously exposed to FeSO4) was found to depend upon the initial FeSO4 loading of the medium, with a saturating concentration 0.5mM FeSO4. Under these conditions 0.86mg/cm^2 of Fe was taken up by the biofilm, but this represented only 16% of that in the system the rest precipitated in the system tubing and reservoir because of the biogenic S^- in solution.

4. Membrane Studies

4.1 Permeable membrane

Investigations into the flow characterisation of the 2.5mm sintered polyallomer PorvairTM permeable membrane showed that a 20-day-old (mature) biofilm made the membrane less permeable, but there was sufficient fluid flow to allow the biocell to be effective at metal removal. Copper sulphate was used as the test heavy metal, fed through the membrane along with the lactate for biofilm metabolism. At high flow rates through the permeable membrane (>0.05mil/min/cm2) copper sulphide formed a suspension and appeared in the waste stream, whereas at lower flow rates, where the contact time between the metal and biofilm was increased, the amount of copper sulphide in the waste stream was reduced to insignificant levels.

4.2 Cross flow operation using a permeable membrane

The biocell was set up with two channels for recirculating liquor separated by a permeable membrane, which supported the growing biofilm. The two recirculating liquor streams were only connected via the permeable membrane. Two main processes were envisaged to transport material between these streams bulk- phase transvection due to a pressure difference between the sides of the biocell and diffusion. Experiments varying the pressure difference across the membrane showed that solutes supplied in the bulk-phase liquor were transported proportionally to the exchange of volume, implying that transvection was the main mechanism. However, sulphide produced by the biofilm was approximately equally distributed between both sides of the biocell even at low-pressure differentials, which produced no bulk-phase movement. This indicated that the sulphide was transported out of the biofilm in both directions by diffusion. When a metabolically-active biofilm was grown on one side of the biocell and metal (Cd) solution was supplied on the other (sterile) side of the biocell, bioprecipitation of the Cd occurred, removing it from solution. Cd was not detected on the biofilm side of the cell so this arrangement, with the biofilm separated from the metal-containing stream by a membrane, permits separation of the metal- containing and nutrient streams reducing any environmental risks from discharge of BOD in the form of nutrients or of toxicity to the biofilm from unprecipitated metals.

5 Modelling Studies

5.1 Biofilm

A model of the biological phenomena occurring within the sulphate reducing bacterial biofilms, has been developed. The model is based upon the Generalised Repository Model (GRM) developed by BNFL. The mechanistic model takes into account a complex microbiology based upon Monod type Kinetic, and incorporates chemical speciation based on the PHREEQE geochemical speciation package. The biofilm code allows the modelling of eight bacterial groups. All microbial groups in each biofilm layer are subject to growth and decay. Microbial growth is modeled via two groups of reactions, energy generating reactions and biomass generating reactions. Bacterial growth and substrate removal is modeled using Monod kinetics, in which substrate removal is related to biomass growth through the yield coefficient. Changes to the bulk chemistry due to microbial activity within the code are utilised as input data by the chemical speciation component of the code, PHREEQE.

The main roles of PHREEQE are the modelling of mineral precipitation and dissolution, speciation of dissolved species, and calculation of the ambient pH. The PHREEQE database has been modified to include lactate and acetate species, which are of specific interest to this project. Species diffuse into the biofilm and an equilibrium is reached between adjacent compartments, (i.e. another biofilm layer or, in the case of the upper biofilm layer, the bulk liquid phase). Microbial degradation changes the concentration of species in the biofilm layers, and compounds diffuse in and out of the layers tending towards equilibrium. Whilst this is occurring the speciation component of the code determines the reaction path of the released species.

Speciation is carried out in the bulk liquid phase, and each of the individual biofilm layers. The rate at which microbial degradation and speciation occur determines the compartment in which the minerals precipitate Species which become incorporated in a mineral phase, by precipitation, remain in that compartment and are not subject to diffusion. The inclusion of advection allows a series of model cells to be connected, allowing a range of experimental and environmental situations to be modeled. After each time step (time taken for speciation, diffusion, and microbiology), species are able to enter and leave the model cells, via adjacent model cells, or an external route.

Microbial growth within each layer is dependent on the diffusion of substrate. The model is based upon a single, or series of model cells, containing a gas phase, bulk liquid phase, biofilm and a substratum.

The model has been success fully applied to results produced by the University of Dundee. It was possible to model the utilisation of lactate and sulphate within the biofilm, and the precipitation of cadmium sulphide with a high degree of success. At present the model has had a limited application, as modeling the BNFL biocell experiments has not utilised the bulk of the models capabilities.

A number of biofilm models are reported in current literature, however none include an extensive microbiology and such a comprehensive speciation component. The model may be applied to further modelling tasks in the future, taking advantage of the full extent of it capabilities.

5.2 Bioreactor Configuration

From the point of view of engineering design, the project has disclosed the following new information:

a) Kinetics

At the start of the project, only one paper was available on tentative reaction kinetics in SRB systems. This project has shown that:

- Sulphide production is zero order in sulphate concentration and exhibits a Monod rate dependence on carbon substrate composition (ignoring complications from acetate utilisation),

- The biofilm kinetics do not alter substantially as the film grows, supporting modeling work presented in the literature on non-SRB systems that there is a constant, active biofilm thickness,

- Sulphide production rate does not appear to be affected by the adsorption of insoluble sulphides and kinetics are dependent on intrinsic kinetics with little effect of diffusional mass transfer in the film,

- As a consequence of the above, a simple form for the local kinetics at a point in a reactor is possible, thereby reducing the computational complexity of previous literature models.

b) Metal precipitation

The form of the precipitation of metal sulphide is very important as it exerts a profound effect on reactor performance and the design of ancillaries to remove insolubles from the reactor outlet stream. This was not realised at the outset of the project and has not, hitherto, been discussed or analysed in the literature. Nonetheless, the experimental and theoretical work in the project has:

- Allowed estimates of the rate of flocculation of colloidal material to be made (which do not appear to be substantially affected by the presence of the biofilm**),**

- Allowed estimates of the rate of biofilm capture of colloidal material to be made, and

- Has shown the conditions under which metal precipitation occurs predominantly either within the biofilm or in the free solution outside the film.

c) Reactor modeling

The few reactor models for SRB systems in the literature have used very complex biofilm kinetics and have not considered practical issues such as flocculation and precipitation. A simple reactor model has been constructed which could be used immediately to interpret the results from a pilot scale reactor. It demonstrates that very careful process control is important in order to achieve the stringent targets with regard to both soluble sulphide concentration and soluble metal concentration in the discharged stream. The model indicates the great sensitivity of the quality of the discharged stream to changes in key parameters.

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.	Second 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, cresols, xylenols, BTEX	
	Costs Documented?	**Project Size**	**Results Available?**
	Not applicable	Not applicable	Yes

1. INTRODUCTION

Natural attenuation 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. Technical protocols are available which provide a basis for the performance assessment of monitored natural attenuation schemes (Buscheck and O'Reilly, 1995; OSWER, 1997). These have primarily evolved from studies of petroleum hydrocarbon and chlorinated solvent spills at sites in North America. However, there is little provision within these protocols for interpretation of natural attenuation within the hydrogeological settings and range of contaminated sites found in the UK and elsewhere in Europe. The U.K. has a legacy of contaminated industrial sites located on deep, consolidated, dual-porosity aquifers and groundwater pollution from these sites often results in the development of complex plumes.

The application of natural attenuation technology requires that there is a framework in place for the robust assessment of its performance at individual sites. This framework needs to incorporate appropriate strategies for monitoring natural attenuation processes *in situ* and predicting the potential for natural attenuation at field scale.

Coal-gasification plants are an important source of soil and groundwater pollution in the U.K. Pollutant streams from these facilities typically contain a wide variety of organic and inorganic compounds (e.g. phenolic compounds and NH_4), usually at very high concentration. These phenolic compounds are normally biodegradable under a range of redox conditions (Suflita *et al.,* 1989; Klecka *et al.,* 1990; Rudolphi *et al.*, 1991). However, in comparison with other groups of organic pollutants our understanding of the fate of pollutants from coal-gasification plants in U.K. aquifers is poor.

2. BACKGROUND

The research site is an operational coal-tar processing and phenols manufacturing plant, constructed in 1950, and situated in the U.K. West Midlands. The plant is located on a deep, unconfined, fractured, Permo-Triassic sandstone aquifer and has contaminated the groundwater with a range of phenolic compounds, including phenol, cresols, xylenols and BTEX, some at concentrations up to 12,500 mg l^{-1}. The aquifer is naturally aerobic, calcareous at depth and contains abundant Fe and Mn oxides as grain coatings. Groundwater levels are shallow (typically <5mbgl) and the aquifer is 250 m thick in the vicinity of the site. Groundwater flow is 4-11 m y^{-1}. The current volume of the plume is about 3 million m^3. The total concentration of organic compounds in the plume source area is presently 24,800 mg l^{-1}, including 12,500 mg 1^{-1} phenol. Site history and groundwater flow patterns suggest that spillages started soon after construction of the plant, that is, the plume is 50 years old. These spillages include mixtures of organic compounds and mineral acids, the latter giving rise to a SO_4 plume with concentrations up to 449 mg l^{-1}. There is no information to indicate when spillages stopped, although the plume remains anchored by a strong source. The only receptor at risk is a public supply borehole, located approximately 2 km west of the plant and >100 y travel time from the present plume.

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 research issues 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 project is funded primarily by the UK Engineering and Physical Sciences Research Council and Environment Agency, with additional contributions from the UK Natural Environment Research Council through affiliated projects. The project began in September 1996, in collaboration with the British Geological Survey, Institute of Freshwater Ecology and University of Leeds, and is 3 years duration. Industrial collaborators include Laporte Inspec, BP, SAGTA and Aspinwall & Co.

3. TECHNICAL CONCEPT

Simultaneous field investigations, laboratory studies and reactive transport modelling have been initiated and are ongoing. The field studies have focused on characterization of the baseline groundwater hydrochemistry and microbiology in the plume. This was undertaken to identify spatial and temporal variations in the distribution of contaminants, redox processes, dissolved gases, microbial population activity and diversity. Two comprehensive groundwater quality surveys have been completed for the suite of 25 monitoring boreholes installed by consultants responsible for the site investigation (Aspinwall & Co., 1992). A basic conceptual process model of contaminant attenuation was developed with this data. High-resolution multilevel groundwater samplers (MLS) have been developed and installed in the plume at 130 m and 350 m from the site, to depths of 30 m and 45 m below ground level, respectively. These devices provide a vertical profile through contaminated and uncontaminated sections of the aquifer at a level of detail unobtainable with the existing borehole network. The MLS boreholes have been used to quantify solute fluxes, degradation rates, redox processes, and identify environmental controls on degradation in the plume. The MLS have been sampled at quarterly intervals over a year to monitor changes in plume redox conditions and microbial population dynamics in response to water table fluctuations in the aquifer. A rock core was recovered anaerobically from the aquifer, adjacent to one of the MLS boreholes, to provide material as inoculum for laboratory process studies, for examination of microbial ecology, for analysis of metal oxide and silicate mineralogy, and for stable isotope characterization of reduced sulphide and carbonate minerals.

Laboratory microcosm studies using acclimated groundwater and aquifer sediment are in progress to examine the degradation rates of phenolic mixtures under the range of redox and environmental conditions found in the plume. The scope of these process studies is wide and includes an assessment of degradation coupled to different aqueous and solid phase oxidants, identifying the contribution of fermentation to degradation and understanding the broad controls on degradation (e.g. oxidant bioavailability and contaminant toxicity). Different redox systems were established in the microcosms under different contaminant concentrations in order to understand the timing and extent of degradation. Initially, aquifer sediment incubated under different redox conditions in boreholes at the site was used as inocula in the microcosms. Additional process studies are now in progress using rock core material recovered from the aquifer. These will examine the spatial variability in aquifer degradation potential, and quantify the bioavailability of mineral oxidants in degradation along a vertical profile through the plume.

Microbiological analysis of groundwater and aquifer sediment samples has focused on understanding the spatial and temporal variability in the diversity and activity of indigenous microbial populations. These variations have been compared for the range of redox conditions and contaminant concentrations found in the plume, to refine the process model developed from the hydrochemical data and to understand the broad environmental controls on microbial ecology and aquifer potential for contaminant degradation.

Reactive transport modelling of biodegradation processes in the plume is ongoing. An initial modelling study was undertaken with the biodegradation code, BIOREDOX, to test the conceptual process model of the plume and to identify additional modelling objectives. Further transport modelling is now underway in collaboration with the University of Waterloo in Canada, using a more advanced code. The necessary parameter values, rate data and processes required for modelling 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 fieldscale.

4. ANALYTICAL APPROACH

Groundwater samples have been collected, anaerobically, for analysis of organic contaminants, dissolved gases (e.g. N_2, CO_2, CH_4), major cations, major anions, organic and inorganic (e.g. total inorganic carbon, Fe^{2+}, Mn^{2+}, S^{2-}) metabolites of phenolic compound degradation, nutrients, $^{34}S/^{32}S\text{-}SO_4$, $^{34}S/^{32}S\text{-}S^{2-}$, $^{13}C/^{12}C\text{-}CO_3^{2-}$, $^{18}O/^{16}O\text{-}SO_4$, organically-complexed and organically-uncomplexed Fe, and micro-biological parameters. Samples have been collected concurrently for analysis of these determinands on each groundwater survey, to provide time-series data for comparison. Geochemical modelling of the groundwater quality data has been completed to identify potential sinks for inorganic products of biodegradation and to refine a carbon mass balance for the plume.

Microbiological analysis has included enumeration of total and culturable bacteria. Direct measures of *in situ* degradation potential have been made on groundwater and aquifer sediment samples by stimulation with NO_3 and addition of radiolabeled phenol compounds and other aromatic hydrocarbons. Microbial diversity has been assessed after inoculation of samples with different nutritional tests.

Rock core samples have been analyzed for oxidation capacity (OXC) and mineral phases (e.g. iron sulphides, metal oxides, carbonates and aluminosilicates). Permeameter tests and analyses of mineral phase $^{34}S/^{32}S\text{-}S^{2-}$ and $^{13}C/^{12}C\text{-}CO_3^{2}$- stable isotopes have also been performed on core samples.

5. RESULTS

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. Contaminant degradation is occurring under aerobic, nitrate reducing, iron/manganese reducing, sulphate reducing and methanogenic conditions, at contaminant concentrations up to 24,000 mg L^{-1}. Degradation rates and microbial activity are highly variable and are correlated with contaminant concentrations and electron acceptor availability in the plume. There is increased microbial activity, diversity and degradation at the plume fringe, in response to the increased flux of dissolved oxygen and nitrate from the background groundwater and dilution of contaminant concentrations. The supply of aqueous oxidants and dilution of contaminants are controlled by mechanical dispersion at the plume fringe. The mixing zone over which this dispersion occurs is relatively small (2 m) for the plume under study. A carbon and electron acceptor mass balance for the plume has constrained the plume source term and suggests that degradation has not been significant within much of the plume (Thornton *et al*., 1998). The mass balance suggests that dissolved oxygen and nitrate, supplied by dispersion, are more important for contaminant mass turnover in the plume than other degradation processes. The stable isotope studies show that a contaminant threshold concentration exists for the initiation of sulphate reduction in the plume, although other degradation processes appear relatively insensitive to the organic pollutant load.

6. HEALTH AND SAFETY

Not available.

7. ENVIRONMENTAL IMPACTS

Not available.

8. COSTS

Not available.

9. CONCLUSIONS

A combination of methodologies has been developed to assess the potential for natural attenuation of organic contaminants at this site. These methodologies include theoretical approaches and practical, field-based, technology which provide an improved framework for understanding the behaviour of complex plumes in aquifers. Contaminant fate in this aquifer system is controlled by a complex plume source history and spatial variations in the aquifer degradation potential, as influenced by contaminant concentration and the bioavailability of oxidants. Source history has a greater impact on contaminant concentrations in this aquifer than degradation processes. The field and laboratory studies show that contaminant mass loss can be demonstrated for the range of environmental conditions found in the plume. However, although the phenolic compounds are biodegradable and the aquifer is not oxidant limited, the plume is likely to grow under the present conditions. This is because contaminant concentrations remain toxic to degradation in much of the plume core and the supply of aqueous oxidants, via mixing with uncontaminated groundwater, is insufficient to meet the demand from the plume. Natural attenuation of these organic pollutants in this system is therefore likely to increase only after increased dilution of the plume.

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Project No. 12

Treatability Test for Enhanced In Situ Anaerobic Dechlorination

Location	Project Status	Media	Technology Type
1. Cape Canaveral Air Station, FL 2. Naval Air Station Alameda, CA 3. Fort Lewis, WA 4. To be determined 5. To be determined	Interim Report	Groundwater	In Situ Bioremediation
Technical Contact	**Project Dates**	**Contaminants**	
Lt. Lisa Ackert AFRL/MLQ 139 Barnes Drive, Suite 2 Tyndall AFB, FL 32403 Tel: 850-283-6308 Fax: 850-283-6064 E-mail: lisa.ackert@mlq.afrl.af.mil	Accepted 1999 Final Report 2001	tetrachloroethylene (PCE) and trichloroethylene (TCE)	
Catherine Vogel DoD SERDP/ESTCP Cleanup Program Manager 901 N. Stuart Street, Suite 303 Arlington, VA 22203 Tel: (703) 696-2118 Fax: (703) 696-2114 E-mail: vogelc@acq.osd.mil	**Costs Documented?** Soon	**Project Size** Field Treatability Testing	**Results Available?** Soon

1. INTRODUCTION

Chloroethene compounds, such as tetrachloroethene (PCE) and trichloroethene (TCE), have been widely used for a variety of industrial purposes. Past disposal practices, accidental spills, and a lack of understanding of the fate of these chemicals in the environment have led to widespread contamination at U.S. Department of Defense (DoD) and industrial facilities. Enhanced anaerobic dechlorination is a very promising bioremediation treatment approach for remediating chlorinated ethene-contaminated groundwater. The goal of this effort is to develop and validate a comprehensive approach for conducting a treatability test to determine the potential for applying reductive anaerobic biological in situ treatment technology (RABITT) at any specific site. A treatability protocol has been written (Morse, 1998) and will be applied to five DoD chlorinated solvent contamination sites in the United States. Based on the field test results, the protocol will be revised as needed upon completion of the effort.

2. BACKGROUND

Because both PCE and TCE are stable compounds that resist aerobic degradation or require the presence of an electron-donating co-contaminant for anaerobic transformation, these compounds tend to persist in the environment. However, in reductive systems, highly oxidized contaminants (e.g., PCE) can be utilized as electron acceptors. RABITT attempts to stimulate this reductive pathway by supplying excess reduced substrate (electron donor) to the native microbial consortium. The presence of the substrate expedites the exhaustion of any naturally occurring electron acceptors. As the natural electron acceptors are depleted, microorganisms capable of discharging electrons to other available electron acceptors, such as oxidized contaminants, gain a selective advantage.

The reductive dechlorination of PCE to ethene proceeds through a series of hydrogenolysis reactions shown in Figure 1. Each reaction becomes progressively more difficult to carry out.

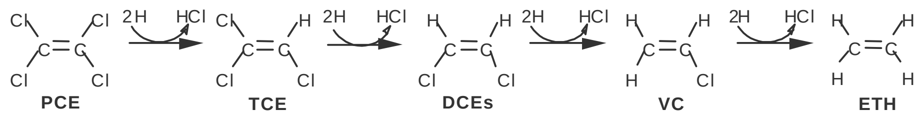

Figure 1. Reductive Dechlorination of PCE

The selection of an appropriate electron donor may be the most important design parameter for developing a healthy population of microorganisms capable of dechlorinating PCE and TCE. Recent studies have indicated a prominent role for molecular hydrogen (H_2) in the reductive dechlorination process (Holliger et al., 1993; DiStefano et al., 1992; Maymo-Gatell et al., 1995; Gossett et al., 1994; Zinder and Gossett, 1995). 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 (Fennell et al., 1997; Smatlak et al., 1996; DiStefano et al., 1992).

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 (Gossett et al., 1994; Fennel et al., 1997). The use of slowly degrading nonmethanogenic substrates will help prevent this type of system shutdown.

Because of the complex microbial processes involved in anaerobic dechlorination, thorough site characterization and laboratory microcosm testing are an important part of the RABITT protocol. The protocol presents a phased or tiered approach to the treatability test, allowing the user to screen out RABITT in the early stages of the process to save time and cost. The protocol guides the user through a decision process in which information is collected and evaluated to determine if the technology should be given further consideration. RABITT would be screened out if it is determined that site-specific characteristics, regulatory constraints, or other logistic problems suggest that the technology will be difficult or impossible to employ, or if competing technology clearly is superior.

The first phase of the treatability test includes a thorough review of existing site data to develop a conceptual model of the site. The protocol contains a rating system that can be used to assess the suitability of a site for RABITT testing. The rating system is based on an analysis of the contaminant, hydrogeologic, and geochemical profiles of the site. The decision to proceed with the RABITT screening process should be supported by data indicating that the site meets the requirements for successful technology application. The second phase of the approach involves selecting a candidate test plot location within the plume for more detailed site characterization. Characterization activities will examine contaminant, geochemical, and hydrogeologic parameters on a relatively small scale to determine the selected location's suitability as a RABITT test plot. Based on the information generated during the characterization of the test plot, a decision is made to proceed to phase three of the treatability study, which consists of conducting laboratory microcosm studies. The microcosm studies are conducted to determine what electron donor/nutrient formulation should be field-tested to provide optimum biological degradation performance. If the results from the microcosm testing indicate that reductive dechlorination does not occur in response to the addition of electron donors and/or nutrients, the technology is eliminated from further consideration. The fourth and final phase of the treatability test entails field testing the electron donor/nutrient formulation determined in the laboratory microcosm tests to be most effective for supporting biologically mediated reductive dechlorination. The data from this phased treatability test indicate the potential for the microbiological component of RABITT and are used to make the decision to proceed to pilot-scale or full-scale implementation of RABITT.

This effort consists of applying the protocol to five chlorinated solvent contamination sites. Currently the field treatability test systems are operating at two locations, Cape Canaveral Air Station, FL and Naval Air Station Alameda, CA. Microcosm studies will begin in August 1999, using contaminated aquifer material from a site at Ft Lewis, WA which is the proposed location for site number three. The fourth and fifth field locations are yet to determined.

3. TECHNICAL CONCEPT

Site #1: Cape Canaveral Air Station, FL

Site Description: Facility 1381, the Ordnance Support Facility at Cape Canaveral Air Station, contains a shallow, 110-acre volatile organic contaminant (VOC) plume consisting primarily of TCE, DCE and VC. Improper disposal of solvents used for cleaning and degreasing operations contributed to this groundwater contamination plume. Field data suggest that TCE is naturally being dechlorinated to DCE and subsequently to VC; however these contaminants have been detected in a surface water body adjacent to the site. This has prompted the state and federal environmental regulators to require a corrective measures study of various remedial options.

The geology at the site is characterized by poorly sorted coarse to fine sands and shell material from ground surface to approximately 35 ft below ground surface (bgs). From approximately 35 ft to 50 ft bgs, sands show a decrease in grain size and the silt and clay content increases. From 48.5 ft to 51 ft bgs, a continuous clay unit appears to underlie the entire area at Facility 1381. Groundwater at the site is very shallow, generally ranging between 4 and 7 ft bgs. The hydraulic conductivity for the shallow groundwater has been determined to be approximately 88.7 ft/day. The pH of the groundwater ranged from 6.87 to 8.14 and conductivity readings ranged from 464 to 5,550 umhos/cm. The groundwater flow velocity has been calculated to be 0.21 ft/day. The suspected source area contains high levels of TCE (up to 342 mg/L) but TCE concentrations drop off quickly and only DCE and VC are detected towards the edges of the plume.

RABITT Testing: The ability of yeast extract, propionate, lactate, butyrate, and lactate/benzoate to stimulate anaerobic dechlorination of TCE was evaluated in laboratory microcosm studies using contaminated aquifer material. Butyrate and the lactate/benzoate mixture stimulated the complete conversion of TCE to ethene. Based on these laboratory results, the decision was made to proceed with the field treatability test.

The standard RABITT field treatability test design consists of an extraction/amendment/reinjection system within a small test plot. Contaminated groundwater is extracted near the end of the treatment plot, amended with nutrients and/or electron donor, and then reinjected near the head of the treatment plot. This design creates a hydraulic gradient to direct the flow of groundwater through the treatment plot. Multi-level monitoring points are placed within the treatment plot, in between the injection and extraction wells. Groundwater extraction and injection are optimized to achieve a 30-day hydraulic residence time within the treatment plot.

This standard RABITT design had to be modified for the site at Cape Canaveral Air Station in order to meet the State of Florida Underground Injection Control regulatory requirements. This regulation does not allow for reinjection of contaminated groundwater. The objective of the modified system was to allow for effective delivery and distribution of nutrients and electron donors and to provide for extensive monitoring and hydraulic control, without pumping groundwater above ground.

The modified design consisted of two communicating wells, a series of 13 tri-level groundwater monitoring probes, and upgradient and downgradient monitoring wells. The system wells are a dual screen design, with one operating in an upflow mode and the other in a downflow mode. The wells are placed close enough to effect each other with the effluent from one well feeding the other. This results in groundwater circulation that can be used to mix and distribute the electron donor/nutrient formulation. The tri-level groundwater monitoring probes are positioned around the treatment cell to provide three-dimensional data that are required to track the tracer and added electron donor/nutrients, calculate mass reductions during treatment, and evaluate gains and losses from the treatment cell through background groundwater migration.

The modified system was installed at Facility 1381 in March 1999 and will operate for six months. The electron donor selected for field-testing was lactic acid. Lactic acid is added to the treatment cell at a concentration and flow rate to achieve an in situ concentration of 2-6 mM.

Site #2: Naval Air Station Alameda, CA

Site Description: Building 360 (Site #4) at Naval Air Station Alameda was selected for the 2nd demonstration. This building has been used as an aircraft engine repair and testing facility, and consisted of former machine shops, cleaning areas, as well as plating and welding shops and parts assembly areas. Solvents used in the cleaning shop of Building 360 have included a mixture of 55% PCE and other chemicals such as dichlorobenzene, methylene chloride, toluene and 30-70% solutions of sodium hydroxide. Site characterization activities performed by the facility revealed elevated levels of chlorinated solvents, primarily TCE (24 ppm), DCE (8.6 ppm) and VC (2.2 ppm) detected between 5.5 and 15.5 feet bgs.

Depth to groundwater in the Building 360 area ranged between 4.4 feet and 6.5 feet bgs. Aquifer testing yielded hydraulic conductivity values from 1.22×10^{-3} to 3.86×10^{-3} cm/sec. The estimated groundwater flow is very low at only 1.1×10^{-5} cm/sec or 11.4 ft/year. It appears that groundwater in this area is very nearly stagnant.

RABITT Testing: The ability of yeast extract, propionate, lactate, butyrate, and lactate/benzoate to stimulate anaerobic dechlorination of TCE was evaluated in laboratory microcosm studies using contaminated aquifer material. Yeast extract, butyrate, and lactate stimulated the complete conversion of TCE to ethene. Based on these laboratory results, the decision was made to proceed with the field treatability test.

The standard RABITT field treatability test was installed at the Alameda site. The system was installed in May 1999 and will operate for six months. The electron donor selected for field-testing was a mixture of butyric acid and yeast extract. Butyric acid and yeast extract are added to the treatment cell at a concentration and flow rate to achieve in situ concentrations of 3 mM butyric acid and 20 mg/L yeast extract.

4. ANALYTICAL APPROACH

A summary of soil and groundwater analytes is presented here. For detailed information on sample collection techniques or analytical methods, please refer to Morse, et al. 1998.

Site Characterization Activities: Soil cores are visually examined for soil type and stratigraphy. In addition, soil core subsamples are sent to an off-site laboratory and analyzed for VOCs, TOC, and Total Iron. Groundwater samples are analyzed for the following parameters; dissolved oxygen, temperature, pH, Fe^{+2}, conductivity, chloroethenes, dissolved organic carbon, ammonia, CH_4, C_2H_4, C_2H_6, NO_3, NO_2, SO_4, Cl, Br, alkalinity, and total iron.

Performance Monitoring of the Field Test Cell: Table 1 presents the performance monitoring parameters and their measurement frequency during field-testing.

Table 1: Performance Monitoring Parameters

Parameter	Measurement Site	Measurement Frequency
TCE, cis-DCE, VC, ethene	Lab	Initial, baseline, and biweekly
Volatile Fatty Acids (electron donor)	Lab	Initial, baseline, and biweekly
Bromide	Field and Lab	Initial, baseline, and biweekly
Dissolved Oxygen	Field	Initial, baseline, and biweekly
pH	Field	Initial, baseline, and biweekly
Conductivity	Field	Initial, baseline, and biweekly
Fe^{+2}	Field	Initial, baseline, and biweekly
CH_4, C_2H_4, C_2H_6	Lab	Baseline and monthly
NO_3, NO_2, SO_4, Cl	lab	Baseline and monthly
Alkalinity	Lab	Baseline and monthly

5. RESULTS

Results from the RABITT field treatability testing at Cape Canaveral Air Station, Naval Air Station Alameda, and Fort Lewis will be presented in the next interim report.

6. HEALTH AND SAFETY

Activities conducted during RABITT system installation and operation that could potentially cause health and safety hazards include drilling with hollow-stem augers or direct push methods, soil and groundwater sample collection, and replenishing concentrated stock solutions (tracer, nutrient, electron donor solutions). Potential hazards include exposure to organic contaminants and other chemicals used in stock solutions, exposure to organic vapors, objects striking feet or eyes, and electrical shock. Appropriate safety precautions and protective equipment is utilized to minimize or eliminate health and safety hazards.

7. ENVIRONMENTAL IMPACTS

Because the contaminants are biologically transformed in situ into non-hazardous compounds (e.g., ethene), the RABITT treatability test does not produce a process waste stream. Characterization and sampling activities generate a small amount of contaminated soil and groundwater that must be properly disposed of.

8. COSTS

Detailed costs for all phases of the RABITT treatability approach will be presented in the final report.

9. CONCLUSIONS

Two of the five planned RABITT treatability test systems have been installed and are currently being monitored. By the time of the Year 2000 NATO/CCMS meeting, three of the tests should be completed and the final two systems will be operating.

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<table>
<tr><td colspan="4">Project No. 13
Permeable Reactive Barriers for In Situ Treatment of Chlorinated Solvents</td></tr>
<tr><td>Location
Dover AFB, DE</td><td>Project Status
Interim</td><td>Media
Groundwater</td><td>Technology Type
In situ abiotic destruction of contaminants</td></tr>
<tr><td rowspan="2">Technical Contacts
Alison Thomas
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E-mail: vogelc@acq.osd.mil</td><td>Project Dates
Accepted 1999
Final Report 2000</td><td colspan="2">Contaminants
Chlorinated solvents: PCE, DCE, TCE</td></tr>
<tr><td>Costs Documented?</td><td>Project Size
Pilot-scale</td><td>Results Available?</td></tr>
</table>

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 this project are to determine the effectiveness of alternative reactive media for the funnel-and-gate system at the field-scale level. Engineering and cost data will also be generated and included in a validated design guidance manual (to be published in late 1999).

2. BACKGROUND

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. TECHNICAL CONCEPT

The main objective of this 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. The validated guidance manual will be distributed at the NATO/CCMS meeting in 2000.

4. ANALYTICAL APPROACH

Groundwater from monitoring points upgradient, downgradient, and within the iron wall is collected and analyzed for the following parameters: PCE, TCE, cis-DCE, dissolved oxygen, conductivity, pH, calcium, magnesium, alkalinity, sulfate, and nitrate.

5. RESULTS

Monitoring done to date indicates that the permeable reactive barrier at Area 5 is performing as designed in terms of contaminant destruction, control of inorganic constituents build up, and hydraulic flow. Although the VOCs currently entering the barrier are at sufficiently high concentrations (60-70 times above their respective drinking water limits) to indicate the effectiveness of the barrier, higher concentrations would make it easier to compare any differences in the performance of the two gates (and the two media). In order to address these issues the following tasks will be accomplished:

(1) Several mini-sampling events will be conducted to measure water levels and sample groundwater (for chlorinated ethenes) from a few select well to monitor influent VOC concentrations.

(2) Another comprehensive monitoring event will be conducted when higher water level conditions are expected in the Area 5 location.

6. HEALTH AND SAFETY

Not available.

7. ENVIRONMENTAL IMPACTS

Not available.

8. COSTS

Cost information will be provided in the final report.

9. CONCLUSIONS

Final conclusions will be presented at the NATO/CCMS meeting in 2000.

10. REFERENCES AND BIBLIOGRAPHY

None.

Project No. 14

Thermal Cleanups using Dynamic Underground Stripping and Hydrous Pyrolysis/Oxidation

Location	Project Status	Contaminants	Technology Type
LLNL Gasoline Spill Site, Livermore, CA. Visalia Pole Yard, Visalia, CA.	Final Report	PAHs, diesel and pentachlorophenol (Visalia) Gasoline (LLNL) (TCE, solvents and fuels at other sites)	Dynamic Underground Stripping and Hydrous Pyrolysis/ Oxidation
Technical Contacts	**Project Dates**	**Media**	
Robin L. Newmark Lawrence Livermore National Laboratory L-208, P.O. Box 808 Livermore, Ca., 94550 United States Tel: (925)-423-3644 Fax: (925)-422-3925 E-mail: newmark@llnl.gov	Accepted 1998	Groundwater and soil	
	Costs Documented?	**Project Size**	**Results Available?**
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	Yes	Full-scale: Livermore: 100,000yd^3 (76,000 m^3) Visalia: 4.3 acres, >130 ft deep (app. 600,000 m^3)	Yes

1. INTRODUCTION

In the early 1990s, in collaboration with the School of Engineering at the University of California, Berkeley, Lawrence Livermore National Laboratory developed dynamic underground stripping (DUS), 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 (HPO), 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.

With dynamic underground stripping, the contaminants are vaporized and vacuumed out of the ground, leaving them still to be destroyed elsewhere. 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. When used in combination, HPO is especially useful in the final “polishing” of a site containing significant free-product contaminant, once the majority of the contaminant has been removed.

2. BACKGROUND

Lawrence Livermore National Laboratory (LLNL) Gasoline Spill Site:

LLNL recently completed the cleanup and closure of a moderate-sized spill site in which thermal cleanup methods, and the associated control technologies, were used to remediate nearly 8,000 gallons (30,000 L) of gasoline trapped in soil both above and below the standing water table. The spill originated from a group of underground tanks, from which an estimated 17,000 gallons (64,000 L) of gasoline leaked sometime between 1952 and 1979. The gasoline penetrated the soil, eventually reaching the water table, where it spread out. Gasoline trapped up to 30 ft (9 m) below the water table was there due to a rise in the water table after the spill occurred, with the gasoline held below water by capillary forces in the soil. Groundwater contamination extended about 650 ft (200 m) beyond the central spill area. The soils at the site are alluvial, ranging from very fine silt/clay layers to extremely coarse gravels, with unit permeabilities ranging over several orders of magnitude. The site was prepared for long-term groundwater pump-and-treat with vapor extraction; recovery rates prior to thermal treatment were about 2.5 gal/day 9.5 L /day).

Visalia Pole Yard:

In 1997, DUS and HPO were applied for cleanup of a 4.3 acre (17,000 m^2) site in Visalia, California, owned by Southern California Edison Co. (Edison). The utility company had used the site since the 1920s to treat utility poles by dipping them into creosote, a pentachlorophenol compound, or both. By the 1970s, it was estimated that 40-80,000 gallons (150,000-300,000 L) of DNAPL product composed of pole-treating chemicals (primarily creosote and pentachlorophenol) and an oil-based carrier fluid had penetrated the subsurface to depths of approximately 100 ft (30 m), 40 ft (12 m) below the water table. Edison had been conducting pump and treat operations at the site for nearly 20 years. While this activity had successfully reduced the size of the offsite groundwater contaminant plume, it was not very effective at removing the NAPL source. Prior to thermal treatment, about 10 lb. (4.5 kg) of contaminant was being recovered per week. Bioremediation of the free-organic liquids is expected be prohibitively slow (enhanced bioremediation was predicted to take at least 120 years).

3. TECHNICAL CONCEPT

Dynamic Underground Stripping (DUS): *mobilization and recovery*

Dynamic Underground Stripping combines two methods to heat the soil, vaporizing trapped contaminants. Permeable layers (e.g., gravels) are amenable to heating by steam injection, and impermeable layers (e.g., clays) can be heated by electric current. These complementary heating techniques are extremely effective for heating heterogeneous soils; in more uniform conditions, only one or the other may be applied. Once vaporized, the contaminants are removed by vacuum extraction. These processes - from the heating of the soil to the removal of the contaminated vapor - are monitored and guided by underground imaging, which assures effective treatment through *in situ* process control.

Hydrous Pyrolysis/Oxidation (HPO): *in situ destruction*

At temperatures achieved by steam injection, organic compounds will readily oxidize over periods of days to weeks. By introducing both heat and oxygen, this process has effectively destroyed all petroleum and solvent contaminants that have been tested in the laboratory. All that is required is for water, heat, oxygen, and the contaminant to be together; hence the name. After the free organic liquids are gone, this oxidation will continue to remove low-level contamination. The oxidation of contaminants at steam temperatures is extremely rapid (less than one week for TCE and two weeks for naphthalene) if sufficient oxygen is present. In HPO, 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. Because the subsurface is heated during the process, HPO takes advantage of the large increase in mass transfer rates, such as increased diffusion out of silty sediments, making contaminants more available for destruction.

Underground Imaging: *process control*

Most subsurface environmental restoration processes cannot be observed while operating. Electrical Resistance Tomography (ERT) has proven to be an excellent technique for obtaining near-real-time images of the heated zones. ERT gives the operator detailed subsurface views of the hot and cold zones at their site on a daily basis. Heating soil produces such a large change in its electrical properties that it is possible to obtain images between wells (inverted from low voltage electrical impulses passed between) of the actual heated volumes by methods similar to CAT scans. Combined with temperature measurements, ERT provides process control to ensure that all the soil is treated.

LLNL Gasoline Spill Site: DUS

The DUS application at the LLNL Gasoline Spill Site was designed to remove free-product NAPL. The targeted volume was a cylinder about 120 ft (36 m) in diameter and 80 ft (24 m) high, extending from a depth of 60 ft (18 m) to a depth of 140 ft (43 m). The water table is located at 100 ft (30 m). Due to the presence of relatively thick clay-rich zones, both electrical heating and steam injection were required to heat the target volume.

Visalia Pole Yard: DUS + HPO

Thermal treatment (DUS steam injection and vacuum extraction) was chosen for removal of the free product contaminant. The overall objectives of thermal remediation of the Visalia Pole Yard are to remove a substantial portion of the DNAPL contaminant at the site, thereby enhancing the bioremediation of remaining contaminant. This is expected to significantly shorten the time to site closure as well as improve the accuracy of the prediction of time to closure. As part of the final removal process, Edison is also implementing hydrous pyrolysis (HPO), an *in situ* method of destroying organic contaminants using small amounts of supplemental air or oxygen. The primary use of HPO at this site is for destruction of residual pentachlorophenol, which will not readily steam strip due to high solubility and low vapor pressure. The combination of rapid recovery and thermal destruction is expected to permit Edison to achieve their cleanup goals, which included termination of groundwater treatment.

A series of noble gas tracer tests were conducted to verify the extent of HPO under field conditions. Evidence of hydrous pyrolysis/oxidation came from the disappearance of dissolved oxygen, the appearance of oxidized intermediate products, the production of CO_2, and the distinct isotopic signature of the carbon in the CO_2 produced, indicating contaminant origin. These results constrain the destruction rates throughout the site, and enable site management to make accurate estimates of total *in situ* destruction based on the recovered carbon using the system-wide contaminant tracking system being used on the site.

4. ANALYTICAL APPROACH

Standard laboratory analyses were performed on all samples unless noted specifically in the references.

5. RESULTS

LLNL Gasoline Spill Site:

During 21 weeks of thermal treatment operations conducted over about a year, DUS treatment removed more than 7600 gallons (29,000 L) of an estimated 6200 gallons (23,000 L) of gasoline trapped in soil both above and below the water table. Prior to thermal treatment, separate phase contamination extended to >120 ft (37 m) deep. Approximately 100,000 yd^3 (76,000 m^3) were cleaned. The maximum removal rate was 250 gallons

(950 L) of gasoline a day. The process was limited only by the ability to treat the contaminated fluids and vapors on the surface.

Dynamic underground stripping removed contaminants 50 times faster than with the conventional pump-and-treat process. The cleanup, estimated to take 30 to 60 years with pump-and-treat, was completed in about one year. As of 1996, following removal of more than 99% of the contaminant, and achievement of Maximum Contaminant Limit (MCL) levels in groundwater for five of the six contaminants, the site is being passively monitored under an agreement with the California Regional Water Quality Control Board (RWQCB), California EPA's Department of Toxic Substances Control (DTSC), and the Federal EPA Region 9. These regulatory agencies declared that no further remedial action is required.

The initial objective of the LLNL DUS demonstration was to remove the separate phase gasoline from the treatment area. Not only was the separate phase gasoline removed, but the groundwater contamination was reduced to or near the regulatory limits. Thermal treatment under these conditions did not sterilize the site, and instead led to the establishment of flourishing indigenous microbial ecosystems at soil temperatures up to 90 • C. The very positive response of regulators, who provided quick closure authorization for the site, indicates that these methods will be accepted for use.

Visalia Pole Yard:

During the first six weeks of thermal remediation operations, between June and August 1997, approximately 300,000 pounds (135 metric tons) of contaminant was either removed or destroyed in place, a rate of about 46,000 pounds (22 metric tons) per week. That figure contrasts sharply with the 10 pounds (0.003 metric ton) per week that Edison had been removing with conventional pump and treat cleanup methods. In fact, the amount of hydrocarbons removed or destroyed in place in those six weeks was equivalent to 600 years of pump-and-treat, about 5,000 times the previous removal rate.

Edison achieved their initial goal of heating over 500,000 yd^3 (380,000 m^3) to at least a temperature of 100 ^oC by the beginning of August 1997. Uniform heating of both aquifer and aquitard materials was achieved. At this point, about 20,000 gallons (76,000 L) of free-product liquid had been removed. Vapor and water streams continued to be saturated with product. Continued destruction by HPO was indicated by high levels of carbon dioxide (0.08 - 0.12% by volume) removed through vapor extraction. Initial destruction accounted for about 300 lb/day 136 kg/day) of contaminant being destroyed via HPO. Operations were changed to a huff and puff mode, where steam is injected for about a week, and then injection ceases for about a week while extraction continues. Maximum contaminant removal is obtained during this steam-off period as the formation fluids flash to steam under an applied vacuum.

In September, 1997, following the initial contaminant removal by steam injection and vacuum extraction, air was injected along with the steam to enhance hydrous pyrolysis of the remaining contaminant. *In situ* destruction rates increased to about 800 lb/day (360 kg/day). Recovery/destruction rates matched expectations. By the summer of 1998, decreasing contaminant concentrations indicated that the bulk of the contaminant had been removed from the main treatment volume. Groundwater concentrations indicated that the site was being cleaned from the periphery inward, with all but two wells showing contaminant concentrations similar to the pre-steam values by September 1998. Active thermal remediation of this zone was nearing completion. At this point, Edison chose to begin injecting steam into a deeper aquifer to heat and remove the remaining contamination that had leaked into the overlying silty aquitard, which represented the "floor" of the initial treatment zone. Contaminant is being recovered from this aquitard today.

In the ensuing months, recovery rates have remained high. As of March 1999, over 960,000 lb (440,000 kg) or 116,000 gallons of contaminant had been removed or destroyed. About 18% of the total has been destroyed in situ via HPO. Contaminant concentrations in the recovery wells are decreasing.

Edison plans to continue steam injection through the end of June 1999. This will be followed by groundwater pumping, vacuum extraction and air injection to enhance HPO and bioremediation. Monitoring of groundwater concentrations is expected to continue for a period of 2 to 5 years.

6. HEALTH AND SAFETY

This high-energy system needs to be handled in accordance with standard safety procedures. Monitoring of air emissions has revealed low emissions with no worker safety or public health impacts.

7. ENVIRONMENTAL IMPACTS

Permits were required for water discharge (treated effluent) and NO_x emissions from the boilers. The site is being remediated under a state-lead Remedial Action Plan (RAP). Vapor is destroyed in the boilers under air permit from the regional air board. Standard regional groundwater monitoring is conducted to ensure public health protection.

8. COSTS

DUS at the LLNL Gasoline Spill Site:

The first application of dynamic underground stripping at the Livermore gasoline spill site in 1993 cost about $110 per cubic yard ($140 per cubic meter); removing the additional research and development costs suggested the project could have been repeated for about $65 per cubic yard ($85 per cubic meter). The alternatives would have been significantly higher. Because contamination at the gasoline spill at the Livermore site had migrated downward over 130 ft (40 meters), digging up the contaminated soil and disposing of it would have cost almost $300 per cubic yard ($400 per cubic meter). Soil removal and disposal costs are more typically in the range of $100 to $200 per cubic yard ($130 to $260 per cubic meter); pump-and-treat method costs are as high as or higher than soil removal costs.

DUS and HPO at the Visalia Pole Yard:

Use of DUS and HPO in combination can permit huge cost savings because HPO eliminates the need for long-term use of expensive pump and treat treatment facilities by converting some contaminants to benign products in situ and mobilizing other contaminants. Site operators can adjust process time to enhance removal DUS or in situ destruction through HPO. Because the treatment is simple, it can be readily applied to large volumes of earth.

Edison has projected the life-cycle cost of steam remediation at the Visalia pole yard to be under $20 million, which includes all construction, operation and monitoring activities. The total treatment zone includes about 800,000 yd^3 (600,000 m^3) of which about 400,000 yd^3 (300,000 m^3) contained DNAPL contamination. Approximately $4.2 million was spent on capital engineering, design, construction, and startup. In addition, about $12 million had been spent on operations, maintenance, energy (gas and electric), monitoring, management, engineering support, and regulatory interface by the end of 1998. Since Edison (the site owner) has acted as primary site operator for the cleanup, the aforementioned project costs do not reflect a profit in the overhead costs. Post-steaming operations will consist of the operation of the water treatment system for an expected duration of two to five years to demonstrate compliance with the California State EPA Remediation Standards. The annual operations and maintenance costs for the water treatment plant is $1.2 million. The previously-approved cleanup plan of pump and treat with enhanced bioremediation was expected to cost $45 million (in 1997 US dollars) for the first 30 years; it was expected to take over 120 years to complete the cleanup.

The Visalia pole yard cleanup is the only commercial 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 ($33/m^3), an enormous savings over current methods. Perhaps the most attractive aspect of these technologies is that the end product of a DUS/HPO cleanup with bioremediation as a final step is expected to be a truly clean site.

9. CONCLUSIONS

Breakthrough cleanups of seemingly intractable contaminants are now possible using a combined set of thermal remediation and monitoring technologies. This "toolbox" of methods provides a rapid means to clean up free organic liquids in the deep subsurface. Previously regarded as uncleanable, contamination of this type can now be removed in a period of 1-2 years for a cost less than the many-decade site monitoring and pumping methods it replaces. The groundwater polishing by HPO provides the means to completely clean serious NAPL-contaminated sites.

The gasoline spill demonstration clearly showed that thermal methods can quickly and effectively clean a contaminated site. With respect to the Visalia Pole Yard cleanup, tremendous removal rates have been achieved. More than 970,000 lb. of contaminants was removed or destroyed in about 20 months of operations; previous recovery amounted to 10 lb/week. Contaminant concentrations are dropping in the extraction wells; the site is cleaning from the periphery inward. Site management plans to terminate active thermal treatment soon, returning to pumping and monitoring the site. The expectations are that groundwater treatment will no longer be necessary after a few years.

The Visalia field tests confirmed *in situ* HPO destruction in soil and ground water at rates similar to those observed in the laboratory, under realistic field remediation conditions. HPO appears to work as fast as oxygen can be supplied, at rates similar to those measured in the laboratory. The predictive models used to design HPO steam injection systems have been validated by using conservative tracers to confirm mixing rates, oxygen consumption, CO_2 release, and effects of real-world heterogeneity. Accurate field measurements of the critical fluid parameters (destruction chemistry, oxygen content, steam front location) were demonstrated, using existing monitoring wells and portable data systems with minimal capital cost.

Several sites are designing DUS/HPO applications similar to Visalia. These include both solvent and pole-treating chemical contaminated sites, ranging in depth from relatively shallow (<40 ft (10 m)) to relatively deep (>185 ft (56 m)). In January 1999, steam injection began at a relatively shallow (>35 ft (11 m)) site in Ohio in which DNAPL TCE is being removed.

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Project No. 15

Phytoremediation of Chlorinated Solvents

Location	Project Status	Media	Technology Type
Aberdeen Proving Grounds Edgewood Area J-Field Site, Edgewood, MD Edward Sears Site, New Gretna, NJ Carswell Air Force Base, Fort Worth, TX	Interim Report	Groundwater	Phytoremediation
Technical Contacts	**Project Dates**	**Contaminants**	
Harry Compton (Aberdeen Site) U.S. EPA, ERT (MS101) 2890 Woodbridge Avenue Edison, NJ 08837-3679 Tel: 732-321-6751 Fax: 732-321-6724 E-mail: compton.harry@epa.gov Steve Hirsh (Aberdeen Site) U.S. EPA, Region 3 (3HS50) 1650 Arch Street Philadelphia, PA 19103-2029 Tel: 215-814-3352 E-mail: hirsh.steven@epa.gov George Prince (Edward Sears Site) U.S. EPA, ERT (MS101) 2890 Woodbridge Avenue Edison, NJ 08837-3679 Tel: 732-321-6649 Fax: 732-321-6724 E-mail: prince.george@epa.gov Greg Harvey (Carswell AFB Site) U.S. Air Force, ASC/EMR 1801 10th Street - Area B Wright Patterson AFB, OH Tel: 937-255-7716 ext. 302 Fax: 937-255-4155 E-mail: Gregory.Harvey@wpafb.af.mil	Accepted 1998 **Costs Documented?** Yes (preliminary)	Chlorinated solvents: TCE, 1122-TCA, PCE, DCE **Project Size** Full-Scale Field Demonstration	 **Results Available?** Yes (preliminary)

1. INTRODUCTION

The efficacy and cost of phytoremediation with respect to the cleanup of shallow groundwater contaminated with volatile organic compounds (VOCs), specifically 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. The contaminant plume presents a low environmental threat.

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, TCE, trimethylbenzene, 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. The trees were planted as a short rotation woody crop employing standard techniques developed by the U.S. Department of Energy (DOE) to grow biomass for energy and fiber. Data are being collected to determine the ability of the trees 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. Duration of evaluation will be five years.
- Various sampling methods were employed during the 1998 growing season to determine if project objectives are being met. The methodologies that yielded the most valuable data include: groundwater sampling, sap flow monitoring, tree transpiration gas and condensate sampling and exposure pathway assessments. In addition to field sampling activities, new trees were planted on the site in October 1998 to increase the phytoremediation area and assess the usefulness of native species for phytoremediation.

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 December 1996.
- 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 April 1996 (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

- Groundwater samples and elevations were collected seasonally from the on-site wells to determine VOC concentrations and if trees were facilitating hydraulic containment of the plume. Results indicate that an area of drawdown exists within the tree zone during the spring and summer when tree transpiration is the greatest. In 1998, additional wells were installed using a Geoprobe in order to more accurately assess VOC concentrations and groundwater elevation. A groundwater model is currently being developed to predict potential VOC removal by the trees and when complete hydraulic containment may be attained. Given the success of the groundwater sampling, sampling objectives for 1999 include groundwater elevation monitoring and sampling and a continued effort to refine the groundwater model.
- 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.
- Sap flow monitoring was performed to determine the amount of water being removed by individual trees. In order to increase monitoring accuracy, new sap flow probes were purchased which are placed directly into the tree tissue as opposed to resting on the trunk of the tree. Comparison of new equipment with previous methods indicates that the new methodology provides an even more accurate estimation of net transpiration rate with less data interference or Anoise@. Future sampling objectives for the site include continued seasonal sap flow monitoring for the purposes of estimating transpiration rates.
- Seasonal tree transpiration gas and condensate sampling continued in the 1998 sampling season to assess the release of VOCs from the trees. Previous methods consisted of placing a 100 liter Tedlar bag over a section of branch and then sampling the gas and any condensate trapped within the bag. This method was modified in 1998 with the addition of a cold trap, which would potentially remove excess moisture from the bag and keep the leaves in a more ambient temperature. Comparison of the two methods, with and

without cold trap, indicate that the cold trap apparatus may not be powerful enough to sufficiently cool the temperature within the bag. Future transpiration gas monitoring is planned for the 1999 sampling season with the addition of a modified cold trap attachment.

- Several studies were designed which examined exposure pathways. Leaves and soil were collected from the phytoremediation area and a reference area for a leaf degradation study. The study is designed to determine whether or not there are deleterious compounds retained within the study leaves or within the associated soil, which could pose risk to an environmental receptor. The results of this study are still being analyzed. Additional studies involved nematode analyses, which examined the trophic assemblage of the nematode community. Data collected in 1997 indicated that the nematode community was enhanced in the phytoremediation area as compared with data collected prior to the tree planting.
- New trees were planted in the 1998 sampling season. The objectives were:1) to assess the phytoremediation capabilities of native Maryland species, tulip trees and silver maples, in addition to hybrid poplar trees; 2) to increase the area of hydraulic containment; 3) to diversify the age of trees to ensure continued containment and contaminant removal and 4) to assess new planting methods. Objective number four relates to the three tree excavations performed in the fall of 1998. Three trees were excavated and replanted in their same areas on the site to examine root depth and structure and whether or not the trees were utilizing groundwater. Examinations revealed that most tree roots appeared to be confined to the hole in which they were placed and did not appear to radiate extensively from this area. It did appear however, that the tree roots were deep enough to access the groundwater. Three new planting methods (i.e. hole sizes and widths) were employed for the new trees in an attempt to provide the tree roots with either increased depth, increased width or a combination of increased width and depth. Future monitoring of these new trees is planned for the 1999 sampling season in an attempt to discern the phytoremediation capabilities of the native species versus the hybrid poplars and to assess the growth of the new trees given the various planting methods employed for each.

Edward Sears Site, New Jersey

- At eight of eleven groundwater sample locations, total VOC levels were lower in 1998 when compared to 1997 total VOC levels at these locations. Order of magnitude reductions in DCE and TCE concentrations were evident at several groundwater sample locations.
- Concentrations of VOC in soil gas and flux samples were negligible. Probably due to the silt/clay lens at 5 feet bgs. These measurements will be discontinued in favor of groundwater monitoring.
- Over 40 direct push, microwells were installed to monitor groundwater in lieu of temporary direct push wells. This will enable more frequent, seasonal monitoring of ground water, at specific locations for comparable costs.
- Sampling of evapotranspiration gas was conducted by placing Tedlar bags over entire trees. Toluene, xylene, 1,3,5-trimethylbenzene, and dichloromethane were detected in low ppb/v levels in some transpiration gas samples. PCE and TCE were not detected.
- Tree height and diameter were adversely affected by high concentrations of VOCs in groundwater. Trees averaged about 5 foot growth for the 1998 season. Some trees in the clean areas grew up to 10 feet in 1998.
- Over a three day period in August 1998, daily sap flow ranged from 70 - 200 gallons/day when applied to the 118 deep planted poplar trees. Water removal by shallow planted trees was not estimated.

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. Studies of the influence of other large trees on the geochemistry of the groundwater in the immediate area of the site indicates that other large trees can alter the chemistry of the groundwater.
- Reduction of dissolved oxygen (DO) is the primary microbial process in the groundwater beneath the planted trees. Two years after planting, the chemistry of the shallow aquifer is changing - DO concentrations are decreasing and total iron is increasing.

- Decaying root tissue and root exudates containing hydrophilic acids are possible sources of labile organic carbon that can be used by microbes to produce anaerobic conditions in groundwater that are conducive to reductive dechlorination.
- The distribution of PCE and TCE transformation products suggest that the highest reducing activity is present in the roots and the highest oxidizing activity is in the leaves. No evidence has been found to indicate that PCE or TCE are accumulated in the leaves.
- Groundwater was sampled in July 1997, November 1997, February 1998, and June 1998. Analyses from theses samples indicate that tree roots have the potential to create anaerobic conditions in the groundwater that will facilitate degradation of TCE by microbially mediated reductive dechlorination. 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.
- 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. USGS review of several synoptic rounds of water level measurements at the site revealed that hydraulic effects on the water table were first observed in the June 1998 data set. Transpiration results from the 1998 growing season were added to the simulation to determine the site wide hydraulic effects of the planted trees. The model results indicate that there was enough transpiration during 1998 to create a drawdown cone on the water table. The field data show the center of the drawdown cone is between the tree stands, which would be expected if one thinks of the principle of superposition. Both the field data and model results indicate that the drawdown cone extends slightly beyond the wells in the upgradient control well. This could explain why some diurnal fluctuation of water levels could be observed during the 1998 growing season.

5. COSTS

Aberdeen Proving Grounds, Maryland

Before treatment C $5,000

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

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

After treatment C None (trees remain in place)

Edward Sears Site, New Jersey

Treatment:

Site Preparation	$24,000
Planting	$65,700
Maintenance	$15,300

Total = $105,000

1997 maintenance: $26,000

1998 maintenance: $14,000*

* Expect maintenance to drop substantially after trees are established

Monitoring/analysis: 50 ground water stations, soil gas, soils, hydrogeological parameters, weather, transpiration gas, reports, etc. Monitoring costs should also reduce annually as study techniques become more refined.

1997: $72,800

1998: $61,600

Carswell AFB, Texas

Before Treatment

Preparatory Work

Site Characterization C $12,000

Site Design C $10,000

Site Work

Monitoring (research level) well installation C $90,000

Development of Plantations - 1 acre (includes landscaping costs) C $41,000

Weather Station C $3,100

Survey C $25,000

Purchase of Trees

Whips ($0.20 each) C $100

Five-gallon buckets ($18 each) C $2,000

Treatment

Installation of Irrigation System C $10,000

Yearly O&M:

Landscaping C $2,000

Groundwater, soil, vegetation, transpiration, climate, soil moisture, and water-level monitoring (research level) C $250,000

The planting costs at Carswell are significantly less than proprietary planting techniques employed by the vendors that involve auguring down to the capillary fringe and other engineered methods for individual tree planting.

After Treatment C None

Project No. 16			
In-Situ Heavy Metal Bioprecipitation			
Location Industrial site in Belgium	**Project Status** New	**Media** Groundwater	**Technology Type** In-situ bioremediation (reactive zone or biobarrier)
Technical Contact Dr. Ludo Diels Dr. Leen Bastiaens Flemish Institute for Technological Research (Vito) Boeretang 200 B-2400 Mol Belgium Tel +32 14 33 51 00 Fax +32 14 58 05 23	**Project Dates** Accepted 1999 Final report 2002	**Contaminants** Heavy metals (zinc, cadmium, arsenic, lead, chromium, nickel, copper) Sulfate	
	Costs Documented? No	**Project Size** Laboratory, pilot/full scale	**Results Available?** Not Yet

1. INTRODUCTION

The industrial world is facing many problems concerning soils and groundwater with heavy metal pollution. This pollution is mainly due to mining activities and non-ferrous activities by e.a. the metal refining, metal processing, and surface treatment industries. Immobilization followed by phytostabilization has been shown to be effective for treating polluted soil in order to reduce the risk of heavy metals being spread around by wind erosion or leaching from the soil into the groundwater (Van der Lelie et al., 1998). But what about groundwater that has already been contaminated with heavy metals?

When dealing with dissolved inorganic contaminants, such as heavy metals, the required process sequence in a ‘pump & treat’ system to remove the dissolved heavy metals present in the groundwater becomes very complex and costly. In addition, the disposal of the metallic sludge, in most cases as a hazardous waste, is also very cost prohibitive. Therefore, in situ treatment methods capable of achieving the same mass removal reactions for dissolved contaminants in an in situ environment are evolving and gradually gaining prominence in the remediation industry.

In this project a relatively innovative technique will be studied for in situ treatment of groundwater containing heavy metals. Through stimulation of sulfate reducing bacteria (SRBs) in aquifers and groundwater heavy metals can be bioprecipitated, hereby reducing the risk of further spreading of the metals. The feasibility of this technique will be evaluated for 2 different industrial sites in Belgium. In-situ bioprecipitation of heavy metals can be implemented as a biological reactive zone or biowall. The concept of in situ reactive zones is based on the creation of a subsurface zone where migrating contaminants are intercepted and permanently immobilized into harmless end products.

2. SITE DESCRIPTION

On industrial site 1 (metal smelter) high concentrations of zinc (10-150 mg/l), cadmium (0.4-4 mg/l) and arsenic (20-270 µg/l) are present in the groundwater. Also relatively high concentration of sulfate (400-700 mg/l) was measured, which is favorable for SRB-activities.

Industrial site 2 (surface treatment) has serious chromium (up to 8300 µg/l), zinc (up to 78 mg/l), lead (up to 72 µg/l), nickel (up to 3500 µg/l), copper (92 mg/l) and cadmium (up to 17 mg/l) problems in the groundwater. Very high sulfate (up to 3000 mg/l) concentrations are also present.

3. DESCRIPTION OF THE PROCESS

Bioprecipitation process:
In-situ precipitation of heavy metals and sulfates is a method based on stimulation of SRBs by supplementing an appropriate electron donor. Addition of extra nutrients (N and P) might also be required for good growth of the bacteria. In the presence of a suitable electron donor (for instance acetate) SRBs reduce sulfates to sulfites and further to sulfides, which then form stable and rather insoluble metalsulfides:

$$CH_3COOH + SO_4^{2-} ==> 2\ HCO_3^{-} + HS^{-} + H^{+}$$

$$H_2S + Me^{++} ==> \underline{MeS} + 2\ H^{+}$$

A good in situ bioprecipitation process however can only be obtained under the following conditions:

- Sulfate reducing bacteria (SRBs) must be present in the aquifer. In case no SRBs are present among the autochthonous micro-population in the aquifer, appropriate microorganisms have to be introduced in the aquifer.
- Sulfate should be available.
- Also nutrients and an appropriate electron donor such as methanol, ethanol, molasses, acetate or lactate are required.
- No oxygen should be present and a low redox potential (E_h) is necessary.

The applicability of in-situ bioprecipitation of heavy metals on sites should therefor be evaluated case by case.

Outline of the project:
- Preliminary study
- Site evaluation
- Lab-scale treatability testing in batch and column experiments
- The presence of SRBs in the aquifers will be examined by microbial countings, measurements of SRB-activity and PCR-technology.
- Selection of a suitable organic substrate
- Determination of optimal physico-chemical conditions: required concentration of the electron donor, nutrients requirement, sulfate requirements, influence of temperature, …
- As the effectiveness of a reactive zone is determined largely by the relationship between the kinetics of the target reactions and the rate at which the mass flux of contaminants passes through it with the moving groundwater, kinetics of metal removal from groundwater will be examined.
- The stability of the formed metalsulfides will be checked.
- Further is clogging due to biomass production and metal precipitates an important issue that has to be evaluated.
- Field demo on pilot of rull scale.
- Monitoring

4. RESULTS/COSTS

Results of this new project will be available the following years.

5. REFERENCES

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Project No. 17 **GERBER Site**			
Location SERMAISE - Department of ESSONNE - ILE DE FRANCE Region	**Project Status** New Project	**Media** Soil and groundwater	**Technology Type** Excavation and treatment of waste
Technical Contact René Goubier ADEME BP 406 49004 ANGERS CEDEX 01 – France	**Project Dates** 06 /1999 07 /2002	**Contaminants** Complex contamination: solvents = BTEX – chlorinated; PCB; phénols, phthalates; Pb, Zn	
	Project Size Full scale		

1. INTRODUCTION

The GERBER site was operated since the beginning of the fifties until 1993 as a solvent regeneration plant. Until 1972, one or two lagoons have been used to dumps residues of the activities. In 1972-1973, an unknown but very important quantity of drums were buried on the site. In 1983, the pollution of the drinking water well of the village of SERMAISE by chlorinated organics was attributed to the GERBER site located in the vicinity and a first preliminary investigation revealed buried drums with organic and chlorinated material.

Nothing happened during the following years because the polluter didn't have the financial capability to carry out significant depollution action. In 1992, in connection with the new legal and financial system created to deal with « orphan » site a first clean up project was carried out by ADEME. The project consisted in the excavation of the main part of the buried drum area: 3700 drums were excavated and treated and 14,000 tons of polluted soil was confined on the site. The treatment of this polluted soil is carried out at the present time by solvent washing. The total cost of these first phases of clean up is about 65 millions francs.

2. THE NEW PROJECT

In addition to the first phase rehabilitation works presented above, it was clear that the remaining part of the site was still heavily polluted with not so much drums but with buried waste corresponding to the ancient lagoons and associated polluted soil and groundwater. Therefore an impact and risk assessment study was carried out in 1998 that characterized the remaining pollution:

- high concentrations of pollutants still cover 70% of the site
- highly contaminated soil was found to a depth of approximately 4-5 m
- total volume of polluted soil is estimated 50-75,000 m^3.

The impact study and modeling showed that the migration of the pollutants in the groundwater seems to be limited and that a two stages natural attenuation occurs: aerobic degradation of BTEX and then reductive dechlorination of chlorinated solvents. Based on these first results it was decided to prepare a new phase of evaluation and corrective action. The objectives of this new phase will be:

- to improve the knowledge of the contamination source and to prepare the clean up of the remaining hot spots
- to complete the evaluation of the transfer of the pollution in the air and in the groundwater with a detailed characterization of the mechanisms of the natural attenuation. Then, after this assessment of the efficiency and limits of the process of natural attenuation an additional project of in situ

source reduction will be studied in order to have finally a restoration system able to reduce the risks to acceptable levels.

Reference - Definition of corrective actions taking into account natural attenuation and risk assessment approach, former Etablissement Chimique du Hurepoix Site in SERMAISE -France - NATO CCMS meeting ANGERS May 1999.

Project No. 18 **SAFIRA**			
Location	**Project Status**	**Contaminants**	**Technology Type**
Bitterfeld, Germany	New project	Complex contamination, chlorobenzene	9 different types of biotic and abiotic technologies
Technical Contact	**Project Dates**	**Media**	
Dr. Holger Weiss UFZ-Centre for Environmental Research Permoserstrasse 15 D-04318 Leipzig Germany	7/1999 - 6/2002	groundwater	
	Costs Documented?	**Project Size**	**Results Available?**
	Yes	Pilot Scale	Not yet

1. INTRODUCTION

The aim of the SAFIRA project is the examination and further development of *in situ* groundwater decontamination technologies. A site near Bitterfeld (Germany) was selected as a model location. Different types of technologies (e.g. catalytic, microbial, sorption) have to prove their performance and long term stability under the real-world conditions of an *in situ* pilot plant. It is a cooperation project between UFZ Center for Environmental Research Leipzig-Halle, TNO (The Netherlands) and the universities Dresden, Halle, Kiel, Leipzig, and Tuebingen.

2. BACKGROUND

The region of Bitterfeld was selected as the model location for investigations into developing powerful *in situ* technologies for the remediation of complexly contaminated groundwater. The soil and water environmental compartments in the Bitterfeld/Wolfen district have suffered sustained damage as a result of over a century of lignite-mining and chemical industry. Whereas relevant soil pollution is mainly confined to industrial locations (plant sites) and landfills, the persistent penetration of the groundwater by pollutants has resulted in contamination attaining a regional scale. Consequently, an area of about 25 km^2 with an estimated volume of some 200 million m^3 is now partly highly polluted and must be regarded as an independent source of contamination. This pollution is characterised by the extensive distribution of halogenised hydrocarbons, especially chlorinated aliphatics and chlorinated aromatics.

3. TECHNICAL CONCEPT

Technology developed and tested in laboratories will be scaled up in two stages: a mobile test unit and an *in situ* pilot plant. A mobile decontamination unit has been designed for this purpose as a "window in the aquifer". Groundwater from a depth of about 20 m is pumped into a storage tank without coming into contact with oxygen. This polluted water will then be used to charge five possible test columns with the physico-chemical conditions of the aquifer being preserved.

The methods tested successfully in the laboratory and in the mobile decontamination unit have to prove their chemical and hydrological long-term stability and will be optimised in a pilot plant. Five shafts with a depth of about 22.5 m and an inner diameter of 3 m were constructed. Several experimental columns of up to 1.4 m in diameter will be installed into these shafts and will be supplied with the contaminated groundwater directly from the aquifer. The contaminated water will vertically flow through the reactors and will be cleaned. Numerous sampling and process controlling facilities as well as a variable design of the reaction columns will enable the analyses of relevant chemical and hydraulic processes during operation and competitive development in technology under real-world conditions. The technologies tested in the first phase of the pilot plant are:

- anaerobic microbial degradation of the contaminants
- aerobic microbial degradation
- electrocatalytical dehalogenation
- zeolith supported catalysts
- oxidizing catalysts
- sorption barriers
- redox reactors
- microbial degradation in combination of adsorption onto several high porosity media
- bioscreens

The assessment of the different techniques will follow chemical, ecotoxicological, economic and environmental criteria.

4. ANALYTICAL APPROACH

A weekly sampling of the inflow and outflow of every reactor will occur. All samples will be analyzed in the laboratory at the site. Regular analyses will include a GC analyses (TCE, DCE, dichlorobenzene, chlorobenzene, benzene), ion-chromatography (chloride, sulfate, phosphate, nitrate), TOC, and AOX. Additional samplings and analysis of water and solid material are optional.

5. RESULTS

First results of the experiments in the laboratory and in the mobile test unit are summarized in reports (see references).

6. HEALTH AND SAFETY

The shafts will ventilated before the staff enter the shafts for sampling. The German regulations for safety have to be followed. The shafts are equipped with warning systems for fire, gas, water, pressure in the reactors, temperature, air quality and controlling the pumps. Most of this equipment is only be necessary for research purpose.

7. ENVIRONMENTAL IMPACTS

The outflow water of the different reactors is cleaned additionally in a cleaning facility. This option was necessary only for the pilot plant to demonstrate the technologies and to avoid environmental impact. The hydrologic regime is not disturbed. Monitoring wells are installed around the shafts.

8. COSTS

Not yet available.

9. CONCLUSIONS

Not yet available.

10. REFERENCES

Weiss H., Teutsch G., Daus B. (ed.)(1997): Sanierungsforschung in regional kontaminierten Aquiferen (SAFIRA) - Bericht zur Machbarkeitsstudie für den Modellstandort Bitterfeld.-UFZ-Bericht 27/1997, Leipzig

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Project No. 19 **Successive Extraction – Decontamination of Leather Tanning Waste Deposited Soil**			
University: University of Istanbul	**Report:** Accepted 1998 Final Report 2000	**Report Status:** Interim	**Project Type:** Laboratory/field
Contact Person: Dr. Erol Ercag University of Istanbul Faculty of Engineering, Department of Chemistry, Avcilar, 34850 Istanbul, TURKEY Tel: 0212 591 1998 Ext. 190 Fax: 0212 591 1997 Ercag@istanbul.edu.tr	**Costs Documented:** None	**Results Available:** None	**Conclusions:** None

1. INTRODUCTION

Since old leather tanning industries have been moved from a central region to the outskirts of Istanbul, namely, from Zeytinburnu to Tuzla of Istanbul, considerable land into which the tanning wastes were dumped over years are now waiting to be reused. Now the Greater City Municipality of Istanbul is considering this emptied region for recreational and housing purposes. This region now poses considerable health hazard for the potential future users of this land.

2. AIM

This project was purported to perform the treatability study of the contaminated soil at Zeytinburnu.

3. METHOD

Sampling of soil over the abandoned tanning industrial area will be made, and the organic + inorganic contaminants in the soil will be analysed. Volatile organic compounds (VOCs) will be analysed by a PhotoIonasation Detector capable of detecting 250+ chemicals.

According to the types of organic (e.g., additives and modification agents) and inorganic (e.g., chromium, sulfide etc.) constituents present as contaminants, a treatability study of soil consisting of organic extraction with suitable solvent (e.g. methylene chloride) followed by acid leaching of toxic heavy metals will be carried out. Both synthetic and real soil samples will be investigated to disclose major constitutents of contaminants and then an optimization study will be carried out to optimize solvent, acid, leachant concentration, solids-to-liquid ratio and so on.

Currently, points from which soil samples are to be taken have already been determined. Several samples are to be taken from the same point according to the distance to the surface. Depth from which samples are planned to be taken will be roughly 1 meter at maximum. At the same sampling positions, VOC measurements will also be made.

4. RESULTS

Not available.

5. COSTS, HEALTH AND SAFETY

Not available.

6. CONCLUSIONS

Insufficient data to draw any meaningful conclusions.

7. REFERENCES

Not applicable.

Project No. 20 **Interagency DNAPL Consortium Side-by-Side Technology Demonstrations at Cape Canaveral, FL**			
Location Cape Canaveral, FL, USA	**Project Status** Nomination	**Contaminants** DNAPL	**Technology Type** 3 Technologies Side-by-Side
Technical Contact Tom Early Oak Ridge National Laboratory P.O. Box 2008 Oak Ridge, TN 37831-6038 Tel: 423/576-2103 Fax: 423/574-7420	**Project Dates** 1998-2000	**Media** Soil and Ground Water	
	Costs Documented? TBD	**Project Size** 2 Acres	**Results Available?** TBD

1. INTRODUCTION

An important step in reducing technology risk and increasing user and regulatory acceptance of DNAPL remediation, characterization and monitoring technologies involves conducting concurrent, "side-by-side" field demonstrations. These side-by-side" demonstrations result in comparative cost and performance data collected under the same field conditions. Through appropriate documentation, the resulting cost and performance data can be evaluated for site-specific applications. Side-by-side demonstrations help to fill an important "gap" in the process of technology development and deployment and will accelerate technology privatization.

2. BACKGROUND

Dense non-aqueous phase liquids (DNAPLs) pose serious, long-term ground water contamination problems due to their toxicity; limited solubility in ground water; and significant migration potential in soil gas, ground water, and/or as separate phase liquids. DNAPL chemicals, particularly chlorinated solvents, are among the most common of environmental contamination problems in the United States as well as for most industrialized countries. There are thousands of DNAPL-contaminated sites in the United States, often at contaminant volumes that are difficult to detect, but in quantities that can represent significant sources of ground water contamination. Many agency and private-sector sites have DNAPL contamination problems, including federal, state, and local government agencies. The Office of Management and Budget estimates that the federal government alone will spend billions of dollars for environmental clean up of DNAPL contamination problems.

While various DNAPL remediation, characterization and monitoring technologies have been demonstrated in the past, it is difficult, if not impossible, to make meaningful comparisons of either performance or cost among these technologies because of the variable conditions at the demonstration sites. As a result, "problem holders" and regulatory officials have been reluctant to deploy these technologies for site clean up. In order to expedite the regulatory acceptance and use of these innovative remedial technologies, comparative cost and performance data must be collected.

3. TECHNICAL CONCEPT

In 1998, a multiagency consortium was organized by the United States Department of Energy/Office of Environmental Management (DOE/EM) and the Department of Defense (DOD) through the Air Force Research Laboratory (AFRL) in cooperation with the 45th space wing, the National Aeronautics and Space Administration (NASA) and the United States Environmental Protection Agency (EPA) to demonstrate innovative DNAPL remediation and characterization technologies at a NASA remediation site on Cape Canaveral Air Station, Cape Canaveral, FL. This Interagency DNAPL Consortium (IDC) was formed to:

- address a serous, wide-spread and shared environmental problem adversely affecting many U.S. federal agencies (e.g., DOE, EPA, DOD, NASA, Department of Interior, Department of Agriculture);

- cost-share the demonstration and comparison of these remediation and monitoring system technologies;

- accelerate both the demonstration and deployment of DNAPL remediation, characterization and monitoring technologies for the purpose of reducing the perceived technology risk associated with these technologies;

- increase regulatory and user acceptance of these technologies by providing documented, cost and performance data; and

- provide increased opportunities to test new sensors designed to support in situ remediation of DNAPL contamination problems in addition to ex situ treatment and disposal.

In order to conduct this side-by-side demonstration, an IDC Core Management Team was organized. The IDC consists of representatives from DOE, NASA, USAF, DOD, and EPA. The Team is a collaborative decision-making body that draws upon the strengths of each agency to solve problems associated with the project. The Team utilizes a Technical Advisory Group (TAG) for support in making decisions that concern individual evaluation of remediation systems. The IDC TAG is comprised of experts from industry, academia and federal agencies. With the support of the TAG, the Team selected three of the most promising remediation technologies for deployment and evaluation at Launch Complex 34.

4. ANALYTICAL APPROACH

In situ oxidation using potassium permanganate is a potentially fast and low cost solution for the destruction of chlorinated ethylenes (TCE, PCE, etc), BTEX (benzene, toluene, ethylbenzene, and xylene) and simple polycyclic aromatic hydrocarbons. In particular, potassium permanganate reacts effectively with the double bonds in chlorinated ethylenes such as trichloroethylene, perchloroethylene, dichloroethylene isomers, and vinyl chloride. It is effective for the remediation of DNAPL, absorbed phase and dissolved phase contaminants and produces innocuous breakdown products such as carbon dioxide, chloride ions and manganese dioxide. The permanganate solution typically is applied at concentrations of one to three percent solution via injection wells. This solution is easily handled, mixed and injected and is non-toxic and non-hazardous.

Bench scale laboratory tests of potassium permanganate with trichloroethylene have resulted in up to a 90% reduction of trichloroethylene in four hours of treatment. The effectiveness of the in situ injection of permanganate is a function of the reaction kinetics, the transport and contact between potassium permanganate and the contaminant, as well as competitive reactions with other oxidizable species (e.g., iron, natural organics). The effective use of this remedial technology requires an engineered approach for maximizing the contact between potassium permanganate and the target contaminant. As with many technologies, low permeability and heterogeneity of soils present a challenge and require a carefully designed application system.

Benefits

- Chemically oxidizes a wide range of organic compounds to innocuous end-products over a wide pH range

- Visible (purple) solution makes it easy to track the injection influence or the degree of treatment

- Chemically stable in water (very slow auto-degradation)–stays in solution until it is reacted

- No off-gas treatment required

Six Phase Soil Heating

The Six Phase Soil Heating technology removes contaminants from soil and ground water by passing an electrical current through the soil matrix. The passage of current generates heat due to electrical resistance within the soil. This is the same process used in any electrically heated device (e.g., clothes iron, heater, stove). Heat is generated throughout the soil in the remediation area and the temperature of the soil is increased to the boiling point of water. Soil moisture becomes steam that is captured by vapor recovery wells for removal. Soil contaminants are vaporized concurrently and are captured for ex situ treatment.

Benefits

- Heat is generated uniformly throughout the treatment volume. While low permeability lenses reduce the performance of other technologies that rely on the vertical movement of a fluid or vapor though the soil matrix, soil heterogeneity or low permeability does not adversely effect Six Phase Soil Heating. In fact, low permeability soils tend to carry greater current than do sandy soils, thus, become hotter, and boil constituents faster.

- Anaerobic dechlorination of solvents will add conductive chloride ions to “hot spots”, likewise attracting current for faster remediation of the impacted regions of the site.

- The boiling of soil moisture in clay lenses forms steam to “sweep out” volatile organic compounds. This steam stripping process effectively increases the permeability clay soils.

- Because Six Phase Soil Heating treats all soils in the treatment volume, there are no untreated regions from which contaminants could diffuse later and cause rebound. Rebound has not been observed at any Six Phase Soil Heating site.

- The presence of perched water does not reduce the effectiveness of Six Phase Soil Heating.

In Situ Thermal Remediation (Steam Injection)

Thermal remediation by steam injection and recovery uses Dynamic Underground Stripping, Steam Enhanced Extraction, Hydrous Pyrolysis/Oxidation, and Electrical Resistance Tomography. Combining these technologies the Dynamic Underground Stripping System uses boilers to generate steam which is then pumped into injection wells that surround the contaminants. The steam front volatilizes and mobilizes the contaminants as it pushes the resulting steam front toward a central network extraction well where it is vacuumed to the surface. Direct electrical heating of soils, clay and fine-grained sediments causes trapped water and contaminants to vaporize and forces them into steam zones where vacuum extraction removes them. Electrical Resistance Tomography is used as a process control method to measure electric resistance and temperatures in the subsurface that allow for real-time control of the heating process.

Benefits

- Faster clean-up, potential closure within months to years, not decades

- Removes source contaminants effectively

- Treats contamination both above and below the water table, with no practical depth limitation

5. RESULTS

To be determined.

6. HEALTH AND SAFETY

To be determined.

7. ENVIRONMENTAL IMPACTS

To be determined.

8. COSTS

To be determined.

9. CONCLUSIONS

To be determined.

10. REFERENCES

Progress reports to be generated

COUNTRY TOUR DE TABLE PRESENTATIONS

ARMENIA

Nowadays the most urgent problems in Armenia are the environmental protection and the rational use of nature resources. The land contamination problem is the priority one from the land resources management problems.

The following Laws and Regulations have been developed and adopted by the Ministry of Nature Protection of Republic of Armenia for ecologically safe and economically effective management of environmental protection:

1. Principles of Nature Protection Legislation in the RA (1991);
2. Land Code of Armenia (1991);
3. Water Code of Armenia (1992);
4. RA Law on the Air Protection (1994);
5. Act of the Republic of Armenia on Environmental impact assessment (1995);
6. Law of Republic of Armenia on Nature Protection and Environmental Management fees and charges (1998.28.12), and corresponding
7. Governmental Decision N864, introducing taxes and fees on atmospheric and water pollution; industrial wastes disposal in landfills, on the use of surface waters, groundwaters and mineral water and on discharges of the industrial sewage (1998.30.12). Operational industrial and transport companies pay taxes and fees, regardless of ownership.

The Land Protection and Hazardous Substances Registration and Control Divisions of Ministry of Nature Protection RA are responsible for the management of contaminated sites in Armenia. There are several sources of land contamination and the following contaminated site types are of major importance in accordance with sources.

Problem of the land contaminated by industrial wastes still remains urgent despite the economic decline in recent years due to the collapse of Soviet Union and numerous socio-economic problems. In Armenia main sources of industrial pollution are due to mining, metallurgical, chemical and construction sectors of industry such as copper-molybdenum factories in Kadjaran, Kapan, copper factory in Alaverdy; gold-extracting factory in Ararat; chemical and cement plants in Ararat, Hrazdan, Yerevan and Vanadzor cities and etc. Their emissions and tails contain a complex of different chemical substances, including heavy metals - lead, cadmium, copper, molybdenum, iron, arsenic and others, and compounds such as fluorine, chlorine, cyanic and nitrogen as well. These chemicals and their compounds can be the source of land and groundwater contamination. About 20 square km of the territory around the Ararat gold-extracting factory had contaminated by heavy metals. The concentrations of heavy metals exceed maximum allowable concentration (MAC) several times.

From the environmental point of view the Kapan, Shaumyan mine deposits are sources of technogenic environmental contamination. The enormous waste volumes have been accumulated during long-term exploitation of mine deposits. The concentrations of copper, lead, zinc in soil, plants and bottom sedimentation are considerably high up to 200 mg/kg, 5 mg/kg and 50 mg/kg accordingly. The total area of high-contaminated sites around the above mentioned mine deposits is 10 square km.

In technogenic zone of Kadjaran factory the land contamination with molybdenum and copper is considerably high too. The average concentration of molybdenum in soil surface layer was 10 mg/kg. In agricultural crops cultivated on such soils (tomato, potato, pepper, beans and fodder crops) concentration of copper and molybdenum is also high.

The technogenic factors impact groundwater too. In mining sites of Kadjaran, Kapan, Alaverdy the content of some chemicals (lead, molybdenum, copper and others) in groundwater have increased in connection with mine deposits development. Their concentration exceeds often the maximum allowable concentration. Now more than 100 kinds of organic pollutants are revealed in groundwaters. The concentration of oil, pesticides, including DDT, DDE, lindane and etc. exceeds maximum allowable concentration tenfold. Thus the groundwater protection from technogenic pollution is also a very important problem.

The landfills are of no less importance in land contamination problem. During the industrial rise (1985-90 years) there were generated about 36.7 million tons of industrial wastes, 20 thousand tons of which were toxic. At present it is difficult to estimate the current rates of industrial waste generation in Armenia. There are no facilities and technologies required for treatment and recovery of recyclable industrial and municipal wastes. Significant part of industrial waste is dumped in municipal waste landfills without any identification and treatment. Municipal waste disposal is carried out not in environmentally and hygienic sound manner. There are 45 urban and 429 rural landfills in Armenia; most of them do not correspond to hygienic requirements and standards. The total territory of landfills covers nearly 1.4 thousand ha. They have been constructed without special permission or environmental impact assessment.

Another source of land contamination is agriculture. Large amounts of biologically active compounds, such as pesticides, penetrate into the environment due to agricultural activity. The average level of pesticides used was 9 kg per ha. In recent years above 20 types of pesticides were applied in Lake Sevan region. Now pesticides import and using quantities are out of control due to privatization of agricultural lands (1992) and destruction of centralized system of pesticides supply. Organochlorine pesticides are considered to be global contaminants as they can circulate in the environment for a long time. The problem of their proper use is still actual nowadays. The application of DDT (1972) and lindane (since 1981 in Lake Sevan region) was banned, as the persistent chemicals, in the former Soviet Union. But there have been determined organochlorine pesticides residues (DDE, lindane) in surface waters of Lake Sevan. In spite of the prohibition the residues of organochlorine metabolites still circulate and are detected in human milk and surface waters. Therefore one of the reasons of organochlorines detection is, probably, the land contamination, as soil is storage for persistent compounds.

Scientists of the National Academy Center of Ecological and Noospheric investigations have developed and begin to implement the method of mapping sites contaminated by heavy metals. It will contribute to the representation of the risk assessment among citizens. Scientists of the Center are working out the technology for the purification of contaminated sites.
Specialists have suggested to undertake efforts to reuse mining wastes of tails in order to extract metals` residues.

The problem of waste management is one of the priority ecological problem in Armenia.The first and very important stage in waste management is collection and analysis of information concerning industrial waste (generation, storage, recycling, utilization, burial etc.) as well as working out the data bank on wastes. At present the waste legislation in Armenia is at the stage of active formation. The aim of the legislative process is to elaborate documentation, which would ensure the most ecologically and economically advisable use of wastes disposal.

The present economic situation in Armenia makes it impossible to do state investments in the field of different environmental programs. Practically there are no governmental funds available for investigations. So with the technical and financial assistance of the International organizations the implementation of programs would be feasible. We expect much benefit from our further collaboration and look forward to joint partnership.

AUSTRIA

1. LEGAL AND ADMINISTRATIVE ISSUES

Austria has no specific national law related to soil protection, but policy in the field of contaminated land was passed in the Federal Act on the Clean-up of Contaminated Sites (ALSAG) in 1989. This act created a national uniform structure for the registration and assessment of contaminated sites and established the prioritisation of sites for urgent attention (including a definition of contaminated sites). However, the main focus of this act is to provide a fund for remediation via a waste tax. The amount of the waste tax is set in the Landfill Ordinance. The Landfill Ordinance 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 mass waste landfills, with each type of landfill legally accepting only certain types of waste. The Landfill Ordinance calls for the pre-disposal segregation of waste streams as well as improved pre-treatment of waste prior to disposal.

Execution of ALSAG is highly related with the Water Act from 1959. The Water Act is based on the precautionary principle and aims to maintain clean water resources. Therefore contaminated groundwater has to be restored to drinking water quality in most cases. These requirements restrict the landuse-dependend setting of clean-up targets.
At present the Federal Ministy of Environment, Youth and Family is working on an amendment to ALSAG which will exclude contaminated sites of the Water Act and allows an improved management of contaminated sites on their current and intended uses. Also the polluter-pays-principle should be strengthened in the amendment.

In order to support sound decision making, the Austrian Standards Institute will publish a standard on “Contamined Sites-Risk Assessment concerning the Pollution of Soil“ in spring 2000.

2. REGISTRATION OF CONTAMINATED SITES

The Federal Environment Agency registered by January 1999 2.476 suspected sites of which 2.303 are landfills and 173 are industrial sites. Deatiled investigations showed so far that 145 sites pose a considerable risk to human health or the environment and therefore were classified as contaminated sites.

In order to support the identification of potentially contaminated industrial sites,the Federal Ministy of Environment, Youth and Family launched a study that identified the main production steps and substances produced of different industrial branches. It is planned to publish a summary of this study by end of 1999.

Remediation projects for registered contaminated sites are fundedn via the Oesterreichische Komunalkredit AG on behalf of the Federal Ministry of Environment, Youth and Family. In the last ten years, 97 remediation projects, with a total cost of ATS 3,4 billion (approx. 283 million US$) were funded.

3. TECHNOLOGY DEVELOPMENT PROGRAM

There is no specific technology development program on a federal level. Initiatives are set on a case-by-case basis. However, current interest focuses on reactive barrier technologies, in-situ bioremediation and various monitoring technologies (bioassays).

4. REMEDIAL METHODS IN USE

"Safeguarding" Methods:	**Number**
capping of landfill	29
extraction of landfill gas	11
enclosure	32
hydraulic measures	38
pump and treat	20
in-situ sorting of material	9

Remediation Methods:	**Number**
excavation off site	24
groundwater remediation	11
soil vapor extraction/bioventing	18
bioremediation	2
soil washing	4
thermal treatment	4
biological treatment	4
immobilisation	4

In some cases, combinations of various treatment technologies have been carried out.

5. RESEARCH AND DEVELOPMENT ACTIVITIES

- 'Application of Bioassays for Risk Assessment and Risk Monitoring of PAH-contaminated Sites', IFA-Tulln, funded by the Federal Ministry for Environment, Youth and Family via Oesterreichische Kommunalkredit AG
- 'Bioremediation in the Rhizosphere', IFA-Tulln, funded by EU DG XII, 4. FP on Environment and Climate 1997
- ‘Bioventing of Hydrocarbon contaminated sites', IFA-Tulln, funded by City of Vienna
- ‘Monitoring Program for Contaminated Soils’, IFA-Tulln
- ‘Age Assessment of HC-based Soil Contaminations`, Fichte Institute, Technical University of Vienna
- ‘Contaminated Sites-Risk Assessment concerning the Pollution of Groundwater’, Austrian Standards Institute
- ‘Contaminated Sites-Risk Assessment concerning the Pollution of Soil’, Austrian Standards Institute
- ‘Recommendation for the Use of Orientating-Values for the Risk Assessment in Austria’, EPA Austria
- ‘Application of Ecotoxicological Testsystems during the Bioremediation of Organic Pollutants in Soil’, IFA-Tulln, funded by Federal Ministry of Science
- ‘Interactions between high volatile chlorinated Hydrocarbons and chlorinated phenols with natural and organophilic Clays’, Inst. for Applied Geology, Vienna
- ‘Development and application of a fractioned Soil Analysis’, Univ. of Soil and Agriculture, Vienna
- ‘Risk Assessment for the Land Application of Sewage Sludge’, Univ. of Soil and Agriculture, Vienna
- ‘Investigation and Assessment of Potential Waste Sites in Styria (Austria)’, Joanneum Research, Graz

BELGIUM

Please note that this tour de table was prepared for the 1998 Annual Report. According to Belgium's country representative, the information is still relevant for the 1999 Annual Report.

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[1], 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.

[1]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

There has been an increased level of activity in the area of hazardous sites within the past year. That increase is within both the private and public sectors with all levels of government participating. As an example, there are now hazardous site working groups active within Environment Canada, where the Regions and Headquarters participate, and across the various government departments.

The best known example of a hazardous site within Canada is the Sydney Tar Ponds where waste disposal practices from a steel making complex has contaminated a large area. The 34 hectares of ponds contain approximately 500,000 tonnes of contaminated material. The contamination includes polycyclic aromatic hydrocarbons (PAHs), heterocyclic nitrogen compounds (HNCs), PCBs and heavy metals.

In late May, the Federal Government and the Province of Nova Scotia announced a $62 Million (Canadian) fund for the tar ponds. The work will include the moving of residents nearest to the site, the channeling of domestic sewage away from the site, health studies and a program for pilot-scale demonstrations of technologies that might be applicable to the remediation of the site.

Further announcements from the Federal Government concerning hazardous sites are expected in the autumn.

CZECH REPUBLIC

1.1 LEGAL AND ADMINISTRATIVE ISSUES

Following laws and decrees concerning environment were issued in the Czech Republic in 1998 and 1999.

Law No.125/1997 Coll., on Waste (New Waste Management Act) entered into force on 1 January 1998 includes two categories of waste: hazardous and others. It was followed with important connected decrees:

- Decree of the Ministry of the Environment of the Czech Republic No. 337/1997 Coll., editing the catalogue of wastes and defining additional list of wastes, with effect of January 1st 1998

- Decree of the Ministry of the Environment of the Czech Republic No. 338/1997 Coll., on details of the waste management, with effect of January 1st 1998.

- Decree of the Ministry of the Environment of the Czech Republic No. 339/1997 Coll., on evaluation of dangerous properties of wastes, with effect of January 1st 1998

- Decree of the Ministry of the Environment of the Czech Republic No. 340/1997 Coll., where the financial reserve resources, details of the creation and usage of these reserves for reclamation, maintenance and decontamination of the landfills after their closing are determined, with effect of January 1st 1998

Law No. 123/1998 coll., on the Right of Access to Information on the Environment entered into force on 1 July 1998. It was issued in the connection with harmonizing of the Czech legislative with the legislative of EU.

Law No.14/1998 on Waters (Small Water Act Amendment) ,with effect of March 6th 1998, changes and completes very old Law No 138/1973 Coll. on Waters (Water Act). The main scopes of it are protective zones of water sources and measures against illegal and improper handling with dangerous substances which causes pollution of surface water and groundwater.

Law No.157/1998 coll. on Chemical Substances and Preparations entered into force of 1 January 1999. It was supplemented with following decrees:

- Decree of the Ministry of the Environment of the Czech Republic No. 340/1997 Coll., where is established a way for risk appraisal of dangerous chemical substances to the environment.

- Decree of the Government of the Czech Republic No.25/1999 Coll., where is established a process of the appraisal of dangerous nature of chemical substances and preparations and the way of their labelling , and a list of classified dangerous chemical substances is issued.

1.2 Registration of Contaminated Sites

a) Major problems

The most widespread pollutants were still oil products (petrol, diesel, kerosene, lubricating and heating oils), chlorinated aliphatic hydrocarbons (DCE, TCE, PCE) in 1998 followed by heavy metals. Organic refractants (PAHs, wood-preserving agents, tars) were more often tackled in 1998 than before.

b) Background information on site registration

- Former SA bases have got complete registration including the records of remediation progress at them in 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.

- Central registration of contaminated sites including waste dumps and landfills has been organised by the MoE (Department of Environmental Damages) with the help of so called „SESEZ“ database. This database has been supplied with data on all old environmental burden, their investigation and remediation since 1996. There are several sources of data: MoE, National Property Fund (NPF) and District Offices. Up today 861 sites, 702 landfills and waste dumps, including logs of 6000 boreholes and wells.

- The MoE - Department of Wastes cooperates with the registration of landfills and waste dumps too.

- The Regional Department in Chomutov (North Bohemia) of the MoE with the financial support of the Zuid -Holland Province organised the project „Inventory of Illegal Wastes Dumps“ in the districts Dìèín, Ústí nad Labem, Teplice, Most, Chomutov, Litomìøice, Louny, Karlovy Vary, Sokolov, Cheb and later Jablonec nad Nisou, in the North Bohemian Region. A huge number of 2000 illegal landfills and waste dumps was found here and priorities of remediation of them were set.

- The National Property Fund has its own registration of those contaminated sites only which remediation is financed by the NPF respectively which were privatised according Act No. 92/1991 and/or contaminated sites (with environmental assessment) of companies which asked NPF for financing of remediation in the process of the second wave of privatisation (from 1992) .

c) Estimated total number of contaminated sites and administration of them

- The preliminary results of the project 530/2/98 have proved that there were about 1600 active landfills which had been used according special conditions of the Law No 238/91 Coll. in the Czech Republic. These landfills are closed now and remediation was finished at 420 localities of them. It is estimated that there were another 250-300 landfills which were used without special, above mentioned conditions. There exist another 2500 - 4000 landfills which had been closed before the effect of the above mentioned law. The most frequent group of landfills and waste dumps is consisted of localities where were (even have been) disposed wastes illegally. The number of them is estimated up to 11 000 (Janoušková 1999).

- There were about 60 contaminated former Soviet Army bases in the Czech Republic. The remediation has been or will be accomplished at the most of them until 2003. The total cost of investigation and remediation of former Soviet bases in the Czech Republic from 1991 to 1998 was over 890 million CZK (Kroová, Krhovský 1999). Only the clean up of the two biggest ones: Mladá - Milovice and Ralsko - Hradèany will last until 2006 and 2008 respectively. Registration of former SA bases is administered by the MoE.

- Eight biggest contaminated Czech military sites being returned to civilian use will be cleaned up until 2000 - 2005. Five other biggest contaminated Czech military sites which are and will be used by Czech Army will be also remediated till 2000-2005. Environmental assessment at the both mentioned groups of sites was carried out according to the 1992 Methodical Instructions. There exist some 300 small contaminated military sites which will be environmentally assessed and some of them remediated step by step. The administration of contaminated site is done by regional offices of the MoD so called VUSS; the central administration is carried out by the MoD.

- The National Property Fund of the Czech Republic administered and registered (and guaranteed remediation there) 300 contaminated sites between years 1991 - 1997 (particularly in the so called second privatisation wave). About 100 contaminated sites from the former privatisation wave are not registered neither guaranteed for their remediation. Financing of clean-up,when provided by the NPF, followed an obligatory environmental audit and, since 1994, a risk assessment analysis. Relevant agreements signed between new owners and the NPF must be approved by the MoE.

- By the end of 1996 a total of 5 550 environmental audits had been carried out in the framework of privatisation. Ten per cent of pollution burden have estimated remediation cost beyond 1 million CZK. The cost in 50 cases was estimated to be more than 500 million CZK The cost of ten cases was estimated over 1 billion CZK (OECD 1999). Five sites have been cleaned up; around 140 sites were in the process in 1998. Hundreds of contracts for remediation of other sites are in preparation. By the end of 1997, 3.3 billion CZK had been spent on clean-up.

- The largest contracts for clean-up between the NPF (and the MoE) and owners were closed with: the Škoda car factory in Mladá Boleslav (Middle Bohemia), the Chemical plants in Litvínov (North Bohemia),), the Ostrava-Karviná Mines (North Moravia- remediation of previous coke plant and chemical plant Ostrava-Karolina) and the Škoda factory in Plzeò (Pilsen) in West Bohemia .

d) Estimated number of sites for future remediation

- Former Soviet bases: 9, planned cost over 469 million CZK, including Milovice-Mladá (Camp and Airfield)-102,9 mil.CZK) and Ralsko- Hradèany Airfield- 299,78 mil.CZK

- Czech military sites: 300

- Illegal waste dumps without known owner or user: over 200: But there is presently no particular programme aiming at the remediation of closed landfills with hazardous waste.

- Contaminated industrial sites guaranteed by the National Property Fund: 300 - 500

- The total cost of clean-up of polluted sites administered by the NPF will be more than 60 billion CZK (OECD 1999).

1.3 Remedial Methods

a) Summary data on remedial methods

- Soils: *ex situ:* bioreclamation (oil hydrocarbons, BTEX, PAHs, PCBs), washing, leaching (heavy metals, PCBs); stabilisation-solidification (HC, PAHs, PCBs); incineration (tars, HC, organic refractants (more or less experimental stage only), poisons), venting (chlorinated hydrocarbons (CHC), HC, BTEX); landfilling (heavy metals, organic refractants, HC, PCBs up to 100 mg/kg d.m.)

- Soils: *in situ:* soil vapour 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), encapsulation by impermeable walls-all pollutants

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

b) Factors influencing use of remedial methods

Hydrogeological and physical properties of soil and rocks, chemical-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), land - use and legislative restrictions, time and money

c) Trends of remediation methods

Hydraulic methods when clean-up of oil pollution will be more and more supplemented with in situ bioreclamation in late phases of decontamination of aquifers.

When both groundwater and soil are contaminated with VOCs (mostly volatile oil hydrocarbons and chlorinated aliphatic hydrocarbons) pump and treat method is to be combined from very beginning with SVE, vacuum extraction and later with air sparging.

For viscous hydrocarbons and organic refractants remediation in general where time aspect is vital, thermal or steam stripping and/or venting should be introduced.
Promising alternative method seems to be flushing of vadoze zone with degradable environmentally safe surfactants completed with groundwater pumping and in situ bioreclamation..

d) Summary evaluation of effectiveness of remediation
The cheapest and most effective and reliable remediation of soil polluted with hydrocarbons is ex situ bioreclamation without any doubts .
When soils are contaminated with volatile HC and simultaneously with CHC the most effective method is soil vapour extraction (SVE).

Pump and treat methods are reliable and versatile but their economy is worsening by each further year or month of clean-up, according the decrease of pollutants concentration. High temperature incineration is too expensive and till now is used for very harmful substances such poisons and some combat chemical only.

1.4 Research , Development, and Demonstration

a) Summary of areas of government-supported RD and D
The Ministry of Environment 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.

The Ministry of Defence has funded areal register/inventory of military sites including contaminated ones with the help of GIS.

b) More detailed information on RD and D can be seen from the following list of research projects and demonstrations.

- Areal register and database 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 till 2000 at least. This project (No. 530/2/98) is listed in the following table.

Table 1 Selected existing research projects concerning water and soil quality of the MoE

No.of project	Beginning	End	Name	Total cost for years 1998-9 (thousand CZK)
510/1/98	1998	1999	Pilot project for the control and introduction of the Directive for quality monitoring of the trounsboundary rivers in the Morava River water catchment area	3 000
510/4/98	1998	2002	Limitation of the areal contamination of surface waters and groundwaters in the Czech Republic	10 500
550/1/98	1998	1999	Indicators of thenatural bioreclamation capacity of rock medium	880
550/2/98	1998	2000	Remedial technologies for removal of contamination with chlorinated hydrocarbons	2 700
530/2/98	1998	2000	Environmental risks evaluation of the closed landfills (which had been used according special conditions relating to the Law Nr.238/1991 Coll., or closed before the effect of the mentioned law); establishing a register for those landfills including the proposal of measures and prioririties	4 200
340/1/97	1997	1999	Impacts of environmental contamination on the state of human health in the Teplice Region	194 248

- Spolchemie a.s.- Ústí nad Labem (North Bohemia). NATO/CCMS Demonstration Project No. 56. Investigation of mercury-contaminated site has started in 1996. The highest Hg concentration of soils were found at the level of 707 mg/kg and in groundwater at 154,1ug/L. Even droplets of liquid mercury in soils were found. Up to several hundred μg/l of chlorinated hydrocarbons were analysed in groundwater too. (EPA1998)

  The risk assessment was updated in 1998. New boreholes found presence of mercury even at depths of 20 m. A pilot test of remediation technology is to be undertaken.

c) Future activities

The MoE has prepared among others the following projects for the next years:

Table 2 Selected new research projects concerning water and soil quality of the MoE

No.of project	Beginning	End	Name	Total cost (thousand CZK)
510/1/99	1999	2002	Protection and use of water sources in a copmplete water catchment	28 000
510/3/99	1999	2001	Conception for the long-term nutrient reduction in the water courses in the Czech Republic	6 050
550/1/99	1999	2001	Groundwater treatment with the help of sorbents of coal origin	3 000
530/2/99	1999	2000	Technologies for the treatment of areas (landfills) strongly contaminated with chlorinated hydrocarbons	1 900

1.5 Conclusions

a) General conclusions

Legislation is under permanent development, when we are harmonizing our legislative with that of EU.
The main problems much more technical than financial ones of contaminated sites are connected with the environmental items of privatisation projects of so called second wave of privatisation. Particularly there are

sometimes discrepancies between aimed decontamination limits of pollution on one hand and the time and economical limitations on the other hand. Both technical and legislative/financial difficulties are and will be connected with environmental assessment end eventual remediation of former waste dumps of unknown owners or users and of the contaminated industrial sites from the so called first wave of privatisation.

b), c) Remedial methods implemented for future

Remediation of fissured aquifers contaminated with chlorinated volatile organics and refractants at whole will pose significant task for future. One of ways how to tackle it will be the above mentioned research grants and the second way may be the demonstration of up-to-date and/or developing technologies. Steam stripping and/or heating and electroreclamation seem to be very promising; however we have till now nearly no experience with them in our country.

We hope that just developing in the frame of NATO/ CCMS activities method of natural attenuation of pollution will help us to tackle non urgent cases of groundwater pollution.

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DENMARK

0. INTRODUCTION

This Tour de Table presentation will focus on ongoing initiatives related to soil contamination. A more detailed description of the legal system, the most important acts and The Programme for Development of Technology, Soil and Groundwater Contamination can be found in the final report from the NATO CCMS meeting in Vienna, Austria 1998.

1. LEGAL AND ADMINISTRATIVE ISSUES

Since the meeting in 1998 the Danish EPA has published two new guidelines in December 1998, and new legislation on soil contamination (The Soil Contamination Act) has been presented to the Parliament on 10 February 1999.

<u>1.1 The New Guidelines</u>

The titles of the guidelines are:

- Remediation of Contaminated Sites no. 6-11 1998,
- Sampling and Analysis of Soil no. 13 1998.

The guidelines on Remediation of Contaminated Sites are presently being translated into English. The guidelines describe how a contaminated site should be handled, beginning with the survey, conducting risk assessments and establishing the required remedial actions.

One of the new elements of the guidelines is that biological degradation under natural conditions is considered in the risk assessment for a limited number of contaminants. A contaminated site is assessed to present a risk to the groundwater resources if the groundwater quality criterion is not satisfied at distance equal to 1 year's groundwater flow. If the groundwater velocity is more than 100 m/yr. then the groundwater criterion must be met at a maximum of 100 m down gradient.

<u>1.2 The Soil Contamination Act</u>

The aim of the Soil Contamination Act is to simplify legislation in this field, by consolidating all regulations on contaminated soil which are presently given in the Environmental Protection Act, the Waste Deposits Act and the Loss-of -Value Act, in one new act on contaminated soil.

Legal practice in particular shows that the Environmental Protection Act and the Waste Deposits Act do not give the authorities the power required to safeguard the "polluter pays principle". A number of the key powers to issue orders or enforcement notices are often insufficient, since they are based on situations where it can be substantiated that the party to whom the enforcement notice is served, acted negligently and, further, had an actual right to dispose of the property to which the notice applies.

This legal vacuum will now be filled with the introduction of the provisions of the Soil Contamination Act, the main elements of which are:

- new system for mapping of contaminated sites
- permission to change land use, allowing mapping of property solely on the basis of suspected pollution, and knowledge that polluting activities may have taken place on the property
- significant change and re-prioritisation of public investigations and remedial measures
- significantly strengthened rules on notices of enforcement
- new rules on disposal and use of soil.

The provisions of the Loss-of-Value Act are carried on in the Soil Contamination Act. The Bill, if adopted, will take effect on January 1, 2000.

1.3. Mapping of pollution
In accordance with the Soil Contamination Act the regional authorities will in the future co-operate with the local councils in the mapping of contaminated sites. Mapping will take place no matter when the pollution took place, and no matter whether it is a point source, e.g. storage tank, or a non-point source, e.g. emissions from industry.

A site is registered on mapping level 1, if actual knowledge is available on activities on the site or activities on other sites which may have been the source of pollution on the site.

A site is register at level 2 if documentation is available allowing us to establish with a high degree of certainty that the site is polluted with substances of a nature and a concentration causing the pollution to be harmful to Man and the environment.

Thus, in the future, sites may be registered on the basis of suspected pollution, contrary to the current Waste Deposits Act and accompanying legislation on registration.

Owners of sites mapped on level 1 or 2 are subjected to a number of restrictions on land use, or users of certain mapped areas (important groundwater areas, residential areas, kindergartens, recreational areas, public areas etc.) must before initiating building or construction work on the site file an application with the regional council. A permit will often be given on the condition that the owner or user carries out the required pollution investigations on his own account. On the other hand building or construction permits are not required for mapped industrial sites, if the use of the site is not changed. However, the municipal authorities must be notified if soil is removed from the site.

1.4 More stringent rules of enforcement
The Soil Contamination Act provides for a number of significantly strengthened enforcement powers, basically only to be applied in relation to pollution occurring after the entry into force of the Act on January 1, 2000.

The Act also empowers the authorities to order investigations, and notices of enforcement to this effect may be served "irrespective of the time the pollution took place", thus also with retrospective application.

The Act empowers the authorities to issue notices of enforcement, no matter how the pollution occurred, and, thus, also when the party to whom the enforcement notice is served acted negligently or by default, thus causing pollution. Exempt from this rule is, however, pollution caused by war, civil unrest, catastrophes of nature etc.

Under the Bill notice of enforcement may, where several polluters are involved, be served to all the parties, based on estimates of their contribution to the pollution. In the future enforcement notices may also be served, no matter whether the polluter still has the right to dispose of the property, provided he had the right to dispose of the property at the time the Bill was presented or later. Moreover, subsequent owners/users must accept investigations, clean-up actions etc. on the site.

Finally, under the Bill (prenotified) enforcement notices may under certain conditions succeed to subsequent operators.

As regards owners of oil tanks with a capacity below 6,000 litres, used for domestic heating, enforcement notices may be served, ordering them to carry out investigations or remedial measures, no matter whether pollution was caused by negligence on their part. These more strict rules on the responsibility of owners of private oil tanks will be combined with a compulsory insurance programme.

2. REGISTRATION OF CONTAMINATED SITES

At present, approximately 40,000 sites in Denmark are potentially contaminated, of these 14,000 sites are estimated to be contaminated and an additional 200 km^2 is estimated to be diffusely contaminated (not including pollution near roads, originating from pollution from traffic).

The last status (published in 1998, data from 1997) on contaminated sites according to the Waste Deposits Act shows that the total number of registered sites was 4,048.

407 new contaminated sites were registered due to field investigations and 98 sites were de-registered due to clean-up activities.

3. TECHNOLOGY DEVELOPMENT PROGRAMME

This part will to some extent cover the Research and Development activities too.

The background and strategies for the development scheme are described in the 'Programme for Development of Technology, Soil and Groundwater Contamination, December 1996'. According to plans it will be available on the Ministry's home page in 1999, at the address: Http://www.mem.dk The programme is also described in the final report from NATO CCMS meeting in Vienna, Austria 1998.

The main aim of the programme is to develop and implement technologies in order to make the clean-up measures more effective at reduced costs.

The Programme for Development of Technology, Soil and Groundwater Contamination is focusing on the following areas of efforts over the next 2-5 years:

1. Soil and/or groundwater contaminated with chlorinated solvents.
2. Soil contaminated with heavy metals.
3. Soil and groundwater contaminated with oil/petrol.
4. Soil contaminated with tar/PAH.
5. Composite contamination.
6. Landfills and leakage of landfill gas.

In 1998 a total amount of DKK 19 million was allocated to the programme.

The Technology Programme for 1998-99 will primarily ensure that methods of remediating contamination that threatens the groundwater are tested and documented. Emphasis should be on contamination with chlorinated solvents and oil/petrol (areas of effort 1 and 3). Furthermore, but to a lesser extent, methods should be tested for remediating soil contaminated with metals (area of effort 2).

<u>3.1 Prioritised field projects for 1998-1999</u>

The points are referring to the areas of efforts, and the following methods or technologies are applied on field projects:

1. Chlorinated solvents

- Dual-phase extraction
- Thermally-assisted remediation
- Modified stripping methods, e.g. well venting and in well stripping
- Natural degradation of chlorinated solvents
- Air sparging

2. Soil contaminated with heavy metals
- Soil washing
- Electrokinetics
- Phyto-remediation

3. Soil contaminated with oil/petrol
- ORC (Oxygen Release Compound)
- Geo-oxidation
- Natural degradation of soil contaminated with petrol/oil

3.2 Studies (elucidation projects**)**
A number of studies are being planned to start in the period 1998-99. Below is a list of some of the expected studies. In addition, other studies may be carried out if the relevant applications are submitted.

The list includes among others:
- Computer models
- Composite contamination
- Soil contaminated with tar/PAH
- Hydraulic and pneumatic fracturing

3.3 Other projects on soil contamination
Below is part of a list of projects which the Danish Environmental Protection Agency is planning to launch. Many of the projects are initiated in order to improve the risk assessment work. The projects are:
- Methods to determine the longitudinal dispersion of the unsaturated zone.
- Development of standards for monitoring contamination of groundwater from down-current point sources.
- Assessment of the pore-water concentration, calculated on the basis of the fugacity principle, by comparisons of flushing tests on selected inorganic substances.
- Development of methods to determine the source-strength concentration (pore-water concentration) by taking soil samples.
- Spread sheet for risk assessment of contamination of soil and groundwater.
- Risk analysis of gasses at landfills.
- Development of methods to measure the effect of contaminated soil and groundwater on the indoor climate

4. REMEDIAL METHODS IN USE

The description in the Tour de Table Presentation from 1998 still covers the range of remedial methods, and the general picture has not changed.

5. CONCLUSIONS

At this point the guidelines mentioned above are implemented.

Hopefully, the Bill on Soil Contamination will be adopted by Parliament in 1999, and enter into force in 2000.

The Programme for Development of Technology is in progress and is adding new and useful knowledge in the area of contaminated soil.

FRANCE

1. LEGAL AND ADMINISTRATIVE ISSUES

a) Background information on Legal and Legislative action

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 3rd 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 1993. 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. This dialogue occurs in many occasions, specially 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.

b) Summary of Legislation

In the case of polluted sites, the basic legal reference is the **law of July 19th 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 15th 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 :

- **Law of July 13th 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 renegociate the sale.

- **Law of February 2nd 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.

- **Law of Dec. 31 1998** (finance law) that creates a new general tax on polluting activities (TGAP). This tax replaces differents previously existing taxes and is applied on air pollution, noise, used oils, treatment / disposal of domestic and industrial waste.

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

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

- circular letter of Dec. 3, 1993 defining the policy for polluted sites

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

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

- circular letter of sept. 1 1997 indicating the possibilities to imply the owner of the polluted site.

c) The concept of polluted sites

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 3rd 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, the definition of a polluted site is : site generating a risk, either actual or potential, for human health or the environment related to the pollution of one of the medias, resulting of past or present activities.

Practically, polluted sites are industrial sites, active or inactive, waste sites, accidental pollution sites.

d) Administrative aspects

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 is the Law on Registred Installations (IC Law, mentioned above in b). The Prefect is assisted by the Inspectors of the Registred 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 7th 1996 gives a detailed definition of the procedure to be carried out by the authoritied to manage the suspected or proven contaminated sites according to the polluter pays principle and, in case of unsuccess, to deal with the orphan sites. This procedure may be explained as follows : in the case a registred 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 the Inspectorate of Registered Installations (*Inspection des Installations Classées*). If the operator don't comply with the order, the Inspector of the Registred Installations writes to the Prefect a 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 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 Commission of the Agency of the Environment and Energy Management (ADEME) to be financed by public funding (TGAP). 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 may require the prefect (circular letter of sept 1. 1997), in the case of unsecess of the action against the operator of the installation, to engage administrative action against the owner. However the existing jurisprudence is rather controversial and the legal validity new position of the Ministry is not proven.

e) Summary of policy developments

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 organise 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 organise the preliminary evaluation and priority ranking of suspected polluted sites. The proposed preliminary evaluation includes two steps :

- *Step A* : which is a documentary study (a historical review and a vulnerability study) based on available and accessible date, 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 programme is prepared.

- *Step B* and the simplifies 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.

- *Simplified Risk Assessment* (SRA) ; 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 3 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 defined guideline values.

At the present time, an other 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 in 1978, limited attention has been given to the problems of land pollution until the beginning of the nineties.

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 databank and reports are periodically issued by the Ministry to inform the public of the situation. A publication of this register was issued in Dec. 1994, gathering 669 sites an other one based on the situation of Dec. 1996 was issued in Dec. 1997, with 896 polluted sites plus 125 sites already restored without any limitation of use.

Inventories

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

a) 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 1998) 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 thousands will require corrective action.

b) 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 departements to order the owners of registered installations to carry out preliminary investigations and simplified risk assessment of their sites. A preliminary classification of priority activities to consider in the orders is given in the annexe of the circular letter. Within 5 years it is previewed that some 1500 to 2000 sites assigned with priority I will be evaluated.

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 approximative 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

a) Summary data on remedial technologies used in the country

According to the datas 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 on third of these cases, a combination of techniques has been used.

b) Policy initiative and other factors influencing the use of remedial methods

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 contraints, landfilling has become more and more difficult and costly.

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

c) Methods used for remediation

Isolation remains one of the most frequently used technique, 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 volatils hydrocarbons and chlorinated solvents in the unsaturated zone. It is sometimes associated with in situ biodegradation (bio-venting). To depolute the satured 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, five thermal treatment installations with various level of performance (quantity and complexity of pollution that can be treated) have been made available in France

4. RESEARCH DEVELOPMENT AND DEMONSTRATION

a) Summery of government supported R & D

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 shree different ways:

- Ministry of the Environment, Section in charge of Research and Economic Affair (SRAE) that develops research programs focusing on behaviour 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 optimise 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).

b) Private R & D programs

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 is 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.

c) Perspectives

According the present time it may be estimated that the R & D programs will be mainly oriented in two directions:

- increase the efficiency of the management of the suspected and provens 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 equipments and processes to caracterise 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...)

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

GERMANY

1. LEGAL AND ADMINISTRATIVE ISSUES

The enforcement of the contaminated site remediation which generally includes the steps registration, risk assessment and remediation is with the 16 Federal States (Länder) of Germany. Together with the Länder regulation more than 35 lists exist all over the country containing different values for risk assessment and clean up. In order to harmonize regulations and values the Federal Government submitted the Federal Soil Protection Act (FSPA) which has been enacted on March 1st, 1999. The accompanying sublegal regulations which have been submitted later on by the Federal Government have been passed the Federal Council (Parliament of the Länder) on April 30th, 1999 with some changes and supplements. It can be expected that the Ordinance on Soil Protection and Contaminated Sites will come into force in July 1999 after the agreement by the Federal Government.

The FSPA includes precaution issues as well as remediation of contaminated soils and sites. The main purpose of the FSPA is to protect against harmful changes in the soil. Harmful changes in the soil exist when the soil functions are impaired and when this leads to danger, to considerable adversely affects for the individual or for the general public. The definition of the FSPA includes natural soil functions and functions of the soil utilization.

The two terms harmful changes in the soil and contaminated sites in the FSPA cover all burdens of the soil which cause hazards for human beings and the environment. Contaminated sites (CS) are defined as sites that cause harmful changes in the soil or other hazards for the individual or for the general public and meet one of the following criteria:

- 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),

Sites that 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.

Following regulations for the remediation of contaminated sites are a substantial part of the FSPA:

- The 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 provide in the case of serious and complex CS transparency and by that provide a substantial contribution to 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 the rule the remedial plan is worked 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 obliged 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 contaminates 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 1998 more than 300,000 SCS were registered excluding military contaminated sites and former armament production sites. More than 100,000 are AWDS and nearly 200,000 are AIS. Due to the different definition of suspected contaminated sites in the Länder according to their legal regulations the data can hardly compared directly.

Table 1:
Status of inventory suspected contaminated sites in Germany (December 1998)

Federal States	Registered suspected contaminated sites		
	abandoned waste disposal sites (AWDS)	abandoned industrial sites (AIS)	sites in all (SCS)
Baden-Württemberg	15.074	27.487	42.561
Bavaria	9.725	3.194	12.919
Berlin	673	5.541	6.214
Brandenburg	5.585	8.580	14.165
Bremen	105	4.000	4.105
Hamburg	460	1.701	2.161
Hesse	6.502	60.372	66.874
Mecklenburg Western Pomerania	4.113	7.231	11.344
Lower Saxony	8.957	k. A.	8.957
North Rhine-Westphalia	17.155	14.874	32.029
Rhineland-Palatinate	10.578	k. A.	10.578
Saarland	1.801	2.442	4.243
Saxony	9.382	22.197	31.579
Saxony-Anhalt	6.936	13.295	20.231
Schleswig-Holstein	3.076	14.497	17.573
Thuringia	6.192	12.368	18.560
Germany total	**106.314**	**197.779**	**304.093**

3. TECHNOLOGY DEVELOPMENT PROGRAM

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

1. for the removal or reduction of contaminants (decontamination measures),

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

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

4. As a consequence of cost considerations the trend for the remediation of contaminated sites is definitely moving towards safequarding and containment measures or excavation and disposal of contaminated soil. As the Länder are responsible for enforcement there are no reliable nation-wide figures on this issue available. However, it can be roughly estimated that almost 50 % of all remediations are executed this way. On the other site the level of applicable decontamination techniques in Germany is very high. This is true for both, the technological facilities of the plants to clean up also highly contaminated soil as well as the capacities that are nation-wide available for the treatment of contaminated soil. Regarding the decontamination of soil, off-site-treatment in stationary plants is meanwhile the main procedure. Table 2 provides the capacities of soil treatment plants of 1996 that have been provided by 4 thermal treatment plants, 24 soil washing plants and 81 biological treatment plants.

Table 2: Capacities of soil treatment plants of 1996

Technology	Capacity [t] in 1996	Soil treated [t] in 1996 / average degree of usage
Biological treatment	1,897,850	1,243,678 / 65.5 %
Soil washing	1,382,900	854,333 / 61.8 %
Thermal treatment	168,000	109,200 / 65.0 %
Together	3,448,750	2,207,211 (64.0 %)

The technology development program, which is mainly funded by the Federal Ministry for Education and Research (BMBF), is executed by the BMBF Project Management Agency for Waste Management and Remediation of Contaminated Sites within the Federal Environmental Agency (UBA). Since the late seventies nearly 300 Million DM have been spent for technology development in the area of remediation.

In the last few years the technology development program is aimed at cost-effective strategies and technologies. These are bioremediation of soil, treatment walls including permeable reactive barrier technologies and natural attenuation.

The Joint Research Group, "Processes for the Bioremediation of Soil," comprises seven joint projects with more than 30 single projects. This interdisciplinary group is working on the development of innovative processes for the bioremediation of contaminated soils. After the laboratory phase, not only their effectivity is tested under application-oriented conditions, but also their success is monitored by a complex control system that goes far beyond a conventional chemical analysis of pollutants. A comprehensive handbook ist scheduled for publication in 1999.

On March 10th, 1999 the BMBF published an announcement „Application of Treatment Walls for the Remediation of Contaminated Sites“. Project proposals for this new joint project are requested till May 31st, 1999.

After initiating R&D-projects on Monitored Natural Attenuation (MNA) as cost-effective possibility for the clean up of military sites by the UBA on behalf of the Federal Ministry for the Environment (BMU - see contribution Axel Szelinski on Natural Attenuation in the Federal Republic of Germany, Background, Trends and Current Situation) the UBA actually is planning to submit the BMBF a new joint project proposal on MNA.

4. CONCLUSIONS

After the recently enacted federal legislation on soil protection and rehabilitation of contaminated sites Germany enters a new phase in both areas. Experiences with the enforcement and execution of the Federal Soil Protection Act have to be gained over the next few years in order to optimize the federal and Länder legislation. Registration of contaminated sites and research and development of remediation technologies are far advanced.

Besides innovative technologies Germany focuses on the development of new strategies and economic instruments for the clean up of contaminated sites. Actually the UBA is involved in a couple of national and international activities on brownfield redevelopment. The UBA has initiated several R&D-projects on this issue and currently chairs the working group 1 „Brownfield Redevelopment“ within the Concerted Action CLARINET funded by the European Commission. In the framework of international activities on the brownfield redevelopment issue the UBA prepares a joint German/British project with industry and university partners to be submitted as a proposal under the 5th Framework Program of the European Commission.

HUNGARY

1. LEGAL AND ADMINISTRATIVE ISSUES

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 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 have been completed in 1-2 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 has approved the National Environmental Program which contains the Remediation Program.

Legislation

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.

2. REGISTRATION OF CONTAMINATED SITES

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 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% of the soil and groundwater and a lesser degree of the air and surface waters.

Priority

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.

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 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.

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.).

Subprograms

- The National Environmental Health Action Plan (NEHAP): Within the frame of the action plan, a database on contaminated areas has been established aiming at evaluting environmental hygiene risks and considering local characteristics and possibilities. Results obtained from survey areas provide a fairly good basis for comprehensive prioritising along the National Remediation Programme.

- The Clean up programme of the Hungarian railway company (MÁV Rt.): The clean up programme was initiated in 1997. All registered contaminated sites of the railway company (railway stations, workshops etc.) are incorporated in the KÁRINFO database of the National remediation Programme.

- The Mining Structure Conversion Programme (SZÉSZEK): The programme was started early on basis of a Government decision of 1991. About 1000 sites have been registered within this programme and the most critical sites have already been remediated. The registered sites of this programme are incorporated in the KÁRINFO database of the National Remediation Programme.

- The Industrial Park Programme: The programme was initiated in 1997 aiming at the reclamation of former industrial zones. It is noted that new industrial parks have also been created by reclamation of old mining properties within the above-mentioned mining programme. Available data from the Industrial Park Programme on old, contaminated industrial sites will be incorporated in the KÁRINFO database of the National Remediation Programme.

- The Military Sites Clean up Programme: The programme is based on the work performed during the preperation of the framework of the National environmental Remediation Programme. Since 1998, the Military Sites Clean up Programme has been financed by the budget of the Ministry of Defence.

- The Governmental Property Privatisation Agency (ÁPV Rt.): Recently, the programme of the privatisation agency has been developed in different fields covering the rest of former Soviet military properties.

3. RESEARCH AND DEVELOPMENT ACTIVITIES

The Remediation Program is coordinated by the Ministry for the Environment 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 Institute for Environmental Development, with the participation of the environmental protection authorities. The office's activities are supervised by the assistant undersecretary of state for the Ministry for the Environment. A team of professionals assigned by the various departments of the ministry assist the assistant undersecretary of state in his duties.

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

Research

Some university institutes were also involved. Technical University of Budapest cooperation with Florida State University had finished a research project on " Monitoring Soil Phytoremediation by Chlorophyll Fluorescence".

Measurement of chlorophyll fluorescence induction kinetics was carried out during a phytoremediation technology field experiment in order to monitor heavy metal uptake from contamination soil. A new portable chlorophyll fluorometer was used to identify the most applicable parameter to monitor the process. Good correlation was demonstrated between this parameter and accumulated heavy metal concentration.Application of the monitoring technique for the technology optimization is proposed.

This project is going to announce as a pilot study.

Implementation of Limit Values

The Hungarian environmental regulations have to be adjusted gradually to the EU standards. Recently, the Ministry for Environment and Regional Policy has prepared a legislation draft, which contains the provision of the groundwater_ directive (80/68/EEC). Among others, it deals indirectly with discharge of contaminants into the groundwater, and in this respect, it also gives some provision about soil protection. It is a demand in Hungary to regulate the standards for proper groundwater quality.

The proposed Hungarian legislation includes the set up of a system of limit values for soil and groundwater:
A: Background values
B: Threshold values of contamination
C: Threshold values of measures
D: Targer values

The complete system of limit values was proposed by an expert group considering the values found in the Dutch and German lists as well as Canadian values and guidelines issued by the US EPA. It is noted that the threshold values and the targer values differ depending on the vulnerability of the aquifers.

Previously, for the most urgent clean-up measures the National Standards for agricultural soils were applied, which are, however, inherently conservative. The ABC values of the Dutch Standards have partly been applied for other clean-up activities. In many cases, the A values of the Dutch standards were not applicable due to the high clean-up costs infolved. Until the new legislation comes into force the Regional Environmental Inspectorates define clean-up criteria on a case-by-case basis.

4. CONCLUSIONS

The process of establishing national-wide inventory of pollution sources and contaminated sites has been initiated. The regional environmental inspectorates have filled in questionnaries distributed by the Remediation Programme Office.

In the framework of the National Environmental Remediation Program a preliminary database containing 173 contaminated sites has been set up. Investigations of soil and groundwater have been made at 23 of these. The expected distribution of type of contaminanants at the sites: 45 % of heavy metals, 20 % of hydrocarbons, 10 % of pesticides, 15 % others, 10 % non identied. 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 1997.

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.

Along the National Environmental Program total clean up costs for all contaminated sites of concern have been estimated to exceed 1 billion US$. In the first 2 years of the remediation program, annual budgets were about 7 million US$. For the year 1999. the same amount would be financed by the central budgets.

JAPAN

1. INTRODUCTION

The PCDD/PCDFs (dioxin) pollution has become the serious social problem in Japan. Extremely high concentrations of dioxin have been detected around the municipal waste incinerators. The waste incineration facilities are thought to the main source of the dioxin emissions (Table 1). The dioxin emissions from the incineration facilities for both municipal and industrial wastes comprise about 90% of the total dioxin emission in Japan.

Table 1. Inventory of dioxin emissions in Japan

Municipal waste incineration	4,300 g/year
Industrial waste incineration	547-707 g/year
Smelter	250 g/year
Petroleum additives (lubricating oils)	20 g/year
Cigarette smoke	16 g/year
Kraft recovery boiler	3 g/year
Lumber and lumber waste incineration	0.2 g/year
Exhaust gas from automobiles	0.07 g/year
Bleached Kraft pulp	0.7 g/year
Agrochemical manufacturing process (PCNB)	0.06 g/year
Total	5,104 – 5,300 g/year

2. NOSE TOWN CASE

In April of 1998, a serious case of the dioxin-contaminated soil in Nose Town, Osaka prefecture, got nationwide news coverage in Japan.

First, the nationwide surveillance of dioxin in off-gases from municipal waste incineration facilities revealed the high concentration of dioxin (150 ng-TEQ/Nm^3) in Nose Town. Because this level exceeded the interim emissions standard of 80 ng-TEQ/Nm^3 (Table 2), the residents requested that the incineration facility in Nose Town should cease operations and that a soil investigation around the incineration facility should be performed. As a result, the maximum concentration of dioxins detected in the soil around the incineration facility and in the bottom sediment of the pond close to the incineration facility was 8,500 ng-TEQ/kg and 23,000 ng-TEQ/kg, respectively. Since extremely high contamination of dioxins in the soil and bottom sediment was observed, the facility was investigated in detail. This investigation resulted in the discovery of several unexpected mechanisms of dioxin contamination. There are several factors for this. The design of this facility (Figure 1), in which scrubber water had been used to decrease the temperature of exhaust gas and the electrostatic precipitator, was unique. Operation and maintenance of the facility were also deficient because the amount of municipal wastes accepted exceeded the planned capacity. Since this incinerator had often burned incompletely, it generated unburned carbons and precursors of dioxins. Furthermore the temperature of the exhaust gas getting into the electrostatic precipitator was about 300 C which is very suitable temperature for *de-novo* synthesis of dioxin. The generated dioxins were concentrated in the scrub unit and some of them accidentally transferred to the cooling unit and diffused to the surrounding area from the cooling tower as a mist. The soil under the cooling water tank was contaminated by the cooling water overflowed. The dioxin concentrations in the soil and the cooling water, in fact, were 52,000,000 ng-TEQ/kg and 3,000,000 ng-TEQ/l, respectively.

There is no residential housing is within a 500-meter radius of the incineration facility. However, the agricultural high school, which is near the incineration facility, has been closed prior to the completion of the soil remediation project. More detailed investigation showed that dioxin concentrations in soils decreased as the increase of distance from the incineration facility and that the patterns of congeners of dioxins were similar. The municipality estimated that the contaminated area is 20,000 m^2 and comprises 4,000 tons of contaminated soil.

3. GUIDELINE VALUE FOR DIOXIN-CONTAMINATED SOIL

The dioxin-contaminated soil has become a serious social problem after the Nose Town incident made the headlines in the newspapers. Japan's Environment Agency organized an expert committee addressing dioxin-contaminated soils in 1998. The expert committee proposed the action level of dioxin in soil at 1,000 pg-TEQ/g (i.e., an intervention value) in residential areas.

In establishing the guideline value, four exposure pathways (Figure 2), i.e., direct ingestion of soil, dermal absorption from soil in direct contact with skin, inhalation of soil particle, and inhalation of dioxin vapor volatilized from soil, were taken into consideration. The value 4 pg-TEQ/kg BW/day was adopted as Tolerable Daily Intake (TDI) value. The Ministry of Health and Welfare estimated that the uptake rate of dioxins through the exposure pathways from foods such as fish and meat and air is 2.58 pg-TEQ/kg BW/day. The expert committee evaluated the soil exposure pathway and determined a range of 0.11 to 0.97 pg-TEQ/kg BW/day if the dioxin concentration in soil is 1,000 pg-TEQ/g.

4. TECHNICAL SUPPORT FOR REMEDIATION TECHNOLOGY DEVELOPMENT

The bench-scale remediation projects for the dioxin-contaminated soil were conducted in 1998 using the dioxin-contaminated soil from Nose Town. In 1999, based on the result of the bench scale test, full-scale demonstrations will be performed.

Based on the monitoring data from the other sites, a comprehensive manual about surveillance and remediation of the dioxin-contaminated soil will be published to support the remedial action by the polluters.

5. FUTURE WORKS

Two major areas need further investigation - dioxin standards in the farmland and in children's playgrounds.

The surveillance of nationwide dioxin concentrations in farmland and agricultural products (i.e., vegetables and fruits) harvested from the farmland is ongoing. Based on these analytical results, a determination on whether or not a farmland standard should be established will be addressed. Some researchers point out that large amounts of dioxin have already accumulated in farmland due to application of pesticides and herbicides such as pentachlorophenol (PCP) and CNP (chlornitrofen, 4-nitrophenyl 2,4,6-trichlorophenyl ether) containing dioxins. Although it is expected that vegetables and other crops do not easily absorb dioxins in soil, there are data addressing the dioxin concentration in the farmland areas in Japan.

Many people have requested that a standard in the soil of children's playgrounds be adopted. Germany has already established a standard value of 100 pg-TEQ/g in children's playgrounds.

There is the problem indigenous to Japan - eating lots of fish and shellfish. The most effective measure to decrease dioxin uptake would be to decrease the amount of dioxin in fish in Japan. The amount of dioxin uptake from fish comprises about 50% of TDI. Bottom sediments are considered to be responsible for the dioxins in fish and shellfish. And dioxin-contaminated soils in residential and farmland areas contribute run-off, which is deposited in rivers, lakes, and coastal areas. It is very important to make clear this long chain pathway from soils to fish.

The latest news is the enactment of the dioxin law on July 12, 1999. Based on the dioxin law, new air, soil, and water quality standards addressing dioxin contamination will be established within six months.

Table 2: "Present" National Regulations for Dioxins

TDI	10 pg-TEQ/kgBW/d	Ministry of Health & Welfare
	5 pg-TEQ/kgBW/d	Environment Agency
	1.4 pg-TDI/kgBW/d	WHO

- Guideline for ambient air quality: 0.8 pg-TWEQ/m^3
- Guideline for soil in residential area: 1,000 pg-TEQ/g
- Emission control for off-gas from wasrte incineration plants
- Potential treatment capability Dioxin conc. (ngTEQ/m^3

(ton/h)	New facility	Old facility
>4	0.1	1
2.4	1	5
<2	5	10
		(after 2002)

Interim regulations for old facilities until 2002: 80 ngTEQ/m^3

Figure 1. The design of the incinerator in Nose Town

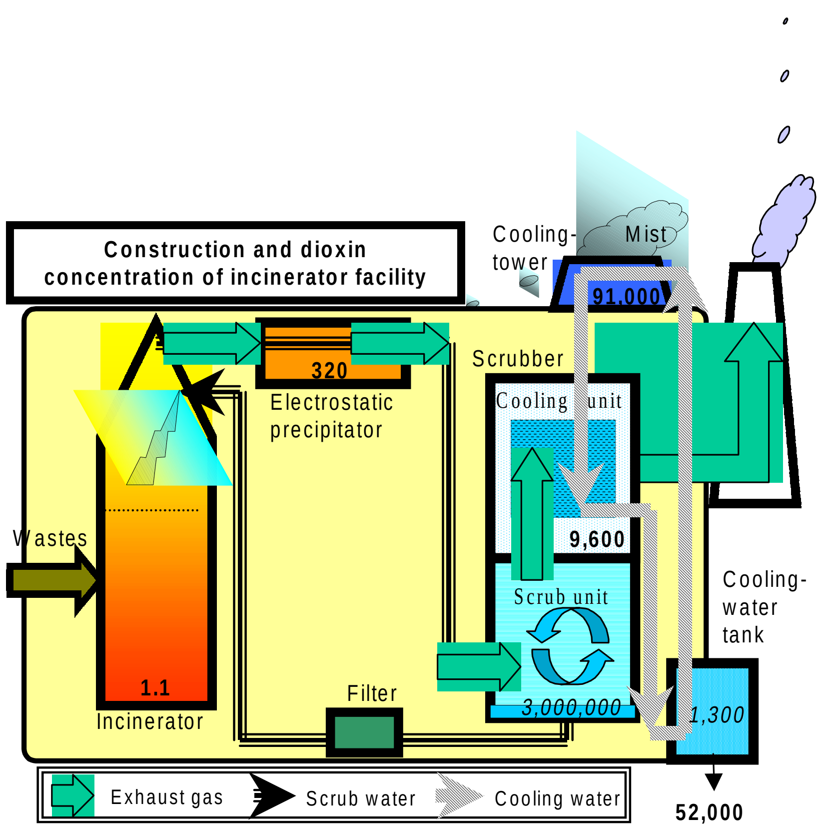
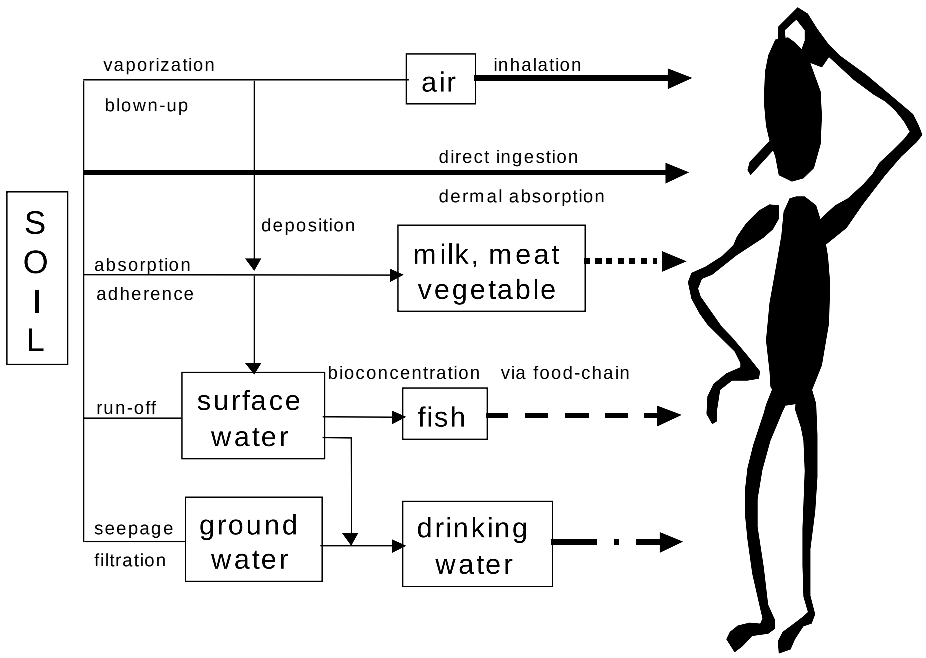


Figure 2: Exposure Pathway from Dioxin-contaminated Soil



Exposure Scenario in Residential Area

- Direct Ingestion
- Dermal Absorption
- Inhalation of Soil Particle (Dust)
- Inhalation of Vaporized

THE NETHERLANDS

1. LEGAL AND ADMINISTRATIVE ISSUES [1]

The Netherlands policy on contaminated land has been focused on the restoration to multifunctionality up to 1998. The application of the multifunctionality approach to the estimated 110,000 seriously contaminated sites would have incurred costs of around 50 billion EURO. The Netherlands is now spending about 0.5 billion EURO 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 has been introduced. This policy development is known by its acronym BEVER.

The new approach abandons the strict requirement for contamination to be removed to the maximum extent, and instead permits clean-up on the basis of suitability for use. At the same time government proposed other changes to soil protection legislation, including greater devolution of responsibility for clean-up 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 optimise 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 organisation of the actual clean-up. These measures taken together are expected to cut costs by 30-50%.

In this approach remediation is part of a comprehensive policy regarding soil contamination. Prevention, land use, 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).

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[1] 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 Dutch government wants to achieve ambitious objects:

- 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%, 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.

In 1999 a lot of attention is paid to the introduction and implementation of the new approach.

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 who don't want to investigate the soil quality on a voluntary basis might be obliged 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 (EURO)
1980	350	0.5 billion
1986	1,600	3 billion
1999	110,000	15-25 billion*

* based on new policy

3. REMEDIAL METHODS

In relation to the policy development, three phases are recognised in the development of remedial methods. In the first phase restoration to multifunctionality 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 non permeable wall barriers and pump and treat. In the latest phase the in-situ technologies have been developed, especially the in-situ bioremediation.

Table 2: Development of technology in the Netherlands

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

In conjunction with the new approach a research programme NOBIS has been 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 has to be achieved. The research programme is supported by the government with 13 million EURO out of the investment fund to improve the infrastructure for the development and exchange of know-how. An additional 7 million EURO has been contributed from the private sector. The programme runs until 1999. There are about 50 ongoing and finished projects.

Due to the impact of NOBIS in-situ bioremediation concepts are more applied now. Especially the concept of natural attenuation has been embraced by many parties (public and private). About 10 projects in NOBIS are dealing with natural attenuation of chlorinated solvents and BTEX.

4. RESEARCH, DEVELOPMENT AND DEMONSTRATION

Starting January 1st, 1999 most of the research on contaminated land is organised in one centre: The Centre for Soil Quality Management and Knowledge Transfer (SKB). The SKB is a co-operative body involving all parties interested in soil management, i.e. trade and industry as well as the authorities, Initially, the activities will be set up for a period of four years (1999-2002), with a possible continuation until 2009.

The mission of SKB is to develop and transfer knowledge about the functional and cost-effective realisation of a soil quality appropriate to the desired use. The mission perfectly matches the new Dutch government policy on soil remediation BEVER, i.e. functional remediation and cost-effective contaminant removal.

A decisive approach to soil contamination and the development of new forms of co-operation must put an end to the stagnation that hampers the optimal use of the little space available in the Netherlands. The SKB wants to achieve this not only through smarter and cheaper technical solutions, but also by devoting attention to managerial processes, rules and regulations, planning and, last but not least, communication. This requires applying existing knowledge on the one hand and developing knowledge via applied andstrategic/fundamental research on the other.

The SKB anticipates initiatives in the following areas of attention:

Urban development and restructuring
Integration of the new development and the restructuring of urban centres in combination with the remediation of contaminated locations, such as former (gas) works sites.

Restructuring natural areas
Nature development and re-designation of agricultural areas in combination with the remediation of former dump sites and contaminated dredging sludge.

Water systems management
Integrating the management of surface water and deep groundwater with the quality of the soil, which consists of earth and groundwater.

Remediation of existing contaminated locations
Developing cost effective remediation strategies ad methods for contaminated locations, in which risk assessment, environmental merit, weighing alternatives and in-situ methods are important issues.

Maintenance and soil management
Risk assessment, management and monitoring of residual (mobile) contaminants will receive increasing attention because it will often be impossible to fully remove the contamination. Moreover, measures will have to be taken to prevent new contamination.

A Supervisory Board is responsible for the policy and officially takes all decisions. Important decisions concern the direction in which the programme will be developed, long term plans, annual action plans and the budget. All parties involved in soil management are represented in the board, namely:

- The ministries of VROM (Housing, Planning Environment), LNV (Agriculture, Nature Management and Fisheries), V&W (Transport and Public Works), Defence, OC&W (Education and Science) and EZ (Economic Affairs).

- The demand side of the market, including trade and industry, provincial and municipal authorities, water boards and managers of rural areas.

- The supply side of the market, including trade and industry, consultants, knowledge institutions and universities.

- Other relevant parties, such as funding organisations, property developers, environmental groups, insurance companies and branch organisations.

The SKB is organised as a demand-driven body for the development and transfer of knowledge. This implies that the organisation does not determine the activities itself, but rather formulates the demand for knowledge and the supply of solutions and avenues for solutions with the interested parties.

The SKB is financed by government (18 million EURO) and by the public private market (8 million EURO) for 4 years: 1999-2002.

5. CONCLUSIONS

The Netherlands policy has been changed drastically in 1997. The introduction and implementation of the new approach is on full swing in 1999. The new approach has also resulted in an increasing demand for knowledge. The SKB, a centre for knowledge development and transfer is stimulating both the introduction of the new approach and the knowledge development.

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 (SFT, short for the Norwegian name). While almost all sites are directly regulated by the national agency, only a few cases are left 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 the national authorities have encouraged municipalities to use this law in their regulatory work and hence contribute to a reduction in 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 national, regional or local authorities, and how and to what extent counties and municipalities should be involved.

Clean up of contaminated sites is 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 save time consuming and costly 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 implementation of a systematic approach for risk assessment are issues of high priority in SFT. This is a part of the decision model for contaminated sites in Norway and reports will be available in English by the end of 1999.

Norway has decided not to apply the principle of “multifunctionality” as the basis for remediation. Because clean-up goals are adjusted to actual or potential land use, site-specific information regarding levels of contamination, remedial measures, land use restrictions etc 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

Registration of contaminated land and contaminated sediments is handled separately in Norway. After the reorganization of the Norwegian Pollution Control Authority in 1998 contaminated sites, contaminated sediments and contamination from old mining areas have been placed in the same unit, to be handled similarly.

3. CONTAMINATED LAND

Contaminated land in Norway is considered as a significant source for contamination of rivers, lakes and fjords. More than 85% of the Norwegian water supply is based on surface water, and consequently groundwater contamination has been of less concern in Norway compared to many other countries. The potential impact from industry, contaminated sediments and landfills on the marine environment is of greater concern. In some fjords 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. More than 2000 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 report and revised plan were presented in the National Budget from the government in 1996. New contaminated sites have continuously been discovered through land development or construction activities.

The actual status shows that more than 3350 contaminated sites are now registered in Norway. About 2100 of these sites are considered to have a potential for causing environmental problems. About 99 of these have been given high priority and investigations and remediation have been started. Additionally ca. 500 sites need to be investigated. The remaining 1500 sites are considered not to represent environmental problems as long as they remain undisturbed (recent land use). Changed land use or construction work will lead to new asessments for these sites.

A GIS-database is developed by the SFT 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 SFT, by the counties and by the municipalities for their planning purposes.

Contaminated sediments

As a result of monitoring of coastal areas and mapping in selected fjords and harbours an overview of sites with contaminated sediments along the coast of Norway was reported and presented, with a priority list, in 1998. More than 120 sites were evaluated and 79 sites are considered as potentially environmentally harmful and given a priority rating from 1 to 3. 18 sites are first priority, 28 second priority and 33 third priority. The information available on these sites is very limited and more investigations are necessary in order to decide how risk of environmental consequences can be reduced or eliminated.

Norwegian authorities consider the system for handeling contaminated land to be acceptable while very little has been done concerning contaminated sediments. This is therefore a major task for the coming years. Evaluation of legislative aspects, marine investigations and research on dredging, treatment and deposition of contaminated sediments have been started and will be given priority over the next 2 – 3 years.

4. REMEDIAL METHODS

An overview of treatment technologies for contaminated land in Norway shows that the following technologies are commercially available through Norwegian companies:

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

In-Situ and Ex-Situ/On Site bioremediation technologies are mainly conducted by consultancies. In total 5 to 10 consulting companies have experience with these technologies. In addition to the consultancies about 3 to 5 companies have specialised in treatment of contaminated soil in Norway as their major activity. They have so far concentrated on solidification/stabilisation, soil washing, land farming and partly incineration. The small number of sites in the ”remediation phase” together with easy access to and low prices on landfills are major reasons for the limited developent and accessibility of treatment technologies on the market.

The SFT 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 consistent asessment by the authorities is of great importance to society.

5. RESEARCH AND DEVELOPMENT

The major development in the field of contaminated land will be to finish and implement the guidelines for risk asessment and general regulation of contaminated soil. Projects concerning applicability of treatment technologies are proposed.

Research projects on deposition of contaminated sediments are a high priority for the National Research Council. SFT focus on aspects such as dredging in fine grained sediments, land fill for contaminated sediments at the coast, and waste deposits of contaminated sediments in deep fjords under naturally anoxic and depositing conditions in the projects. Further investigations are to be started in 5 – 6 of 18 first priority fjords and harbours. Competence and experience on investigation, environmentally acceptable dredging, and construction or establishing of waste deposits for contaminated sediments and soils on shore at the coast and under water, are to be developed.

6. CONCLUSIONS

The Norwegian Pollution Control Authority has the following priorities:

- 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 thereby saving time consuming and costly processes
- Implementation of a system for site specific risk assessment, including target values for sensitive land use, as a part of the decision model for regulation of contaminated land.
- Development of guidelines for management of excavated contaminated soil.
- Starting investigations in areas with contaminated sediments in order to be able to decide remedial action.
- Research and development concerning handling of contaminated sediments.

ROMANIA

The institutionalizing of the activity of the environmental protection in Romania took place in 1990 by setting up the Ministry of Water, Forestry and the Environmental Protection (MAPPM). By that time, there existed, at national level, the National Council for the Environmental Protection as a representative institution without any executive prerogatives organized according to the Law on the Environmental Protection No 9 of 1973.This law was replaced in 1995 by the Law on the Environmental Protection No.137, a law containing stipulations and approaches according to the European Legislation.

At the level of the local administrative structures, in 41 counties, the Ministry of Waters, Forests and the Environmental Protection is represented by the Environmental Protection Agencies. The global legislative frame is extremely complicated and undergoing a continuous process of adjustment due to the economic transition, to privatizing and transfer of land ownership, situation that also affects the legal frame of the protection of the environment in Romania.

The main polluting source of the soil and of the underground waters is represented by the industrial activity from mining, petrochemistry, metallurgy, the industry of fertilisers and the power energy.

1. LEGAL AND ADMINISTRATIVE ISSUES

The Law on the Environmental Protection, promulgated in 1995, establishes the general framework for the activities of the environment protection in Romania, the prerogatives of central and local authorities, of the local and national public administration together with the principles and the strategic elements for sustainable development. An important stipulation refers to the obligation of maintaining, improving the quality of the environment together with the reconstruction of the damaged areas.

The law contains prerogatives referring to the procedure of permitting the activities with impact upon the environment, regulations for dangerous wastes and substances, regulations for fertilisers and pesticides, waters protection, the protection of natural resources, the protection of the soil and subsoil and specifies the responsibilities of the physical and juridical persons, of the public administration and the Environment authorities for observing the requirements of his law.

Based on the prerogatives of the Constitution of Romania and on the Law on the Environmental Protection, in the field of decontaminating and cleaning up the polluted sites and the underground waters there has been created a favorable legislative framework which is under continuous improving and completion.
Similar stipulations can also be found both in The National Strategy of the Protection of the Environment in Romania and in the National Plan for Action for the Environmental Protection.

Along this period of time a series of complementary legislative acts have been issued including stipulations regarding the rehabilitation of the polluted sites and of the underground waters on a priority level in Romania's policy for the environment:

- The Law of the Real Estate No. 18/1991
- The Law on Waters Protection No. 107/1996
- Law No. 6/1991 regarding the adherence to the Convention of Basel concerning the cross-border transportation of the dangerous wastes.
- The Law of the Mines No. 6/1998
- The Law of the Local Public Administration No. 69/1991 republished and modified in 1996.
- The Law No. 137/1996 regarding the collecting, recycling and the use of reusable wastes.
- The Law of Privatizing the Commercial Companies state owned
- Governmental Decision 437/1992 regarding the system of wastes importing.
- Governmental Decision 155/1999 regarding the introduction of the wastes evidence and the European Catalogue of Wastes.

- Governmental Decision no. 55/1998 regarding the Privatizing of the Commercial Partnerships with capital of state.
- Governmental Decision no. 816/1998 regarding the conserving and the final closing up of some mines and quarries.
- Governmental Decision no. 17/1999 regarding the conserving and the final closing up of some mines and quarries - second stage.
- Governmental Decision no. 511/1994 regarding measures for controlling the pollution of the environment by companies that produce polluting wastes.
- Ministry Bill of MAPPM no. 125/1996 regarding the permitting procedure for the economic activities having an impact upon the environment.
- Ministry Bill of MAPPM no. 184/1998 regarding the content of the impact studies and of the environmental assessment
- Ministry Bill of MAPPM no. 756/1998 regarding the evaluation of the environment pollution.
- Ministry Bill of MAPPM no. 111/1999 regarding the entitling of the companies to make ecological improvements and make some workings for closing up the mines
- The Bill of the Agency for Mineral Resources No.6/1999 regarding the procedure of concession of the right for exploiting the mineral resources.
- The Bill of the National Agency of the Mineral Resources No 116/1998 regarding the technological regulations for closing up the mines.
- Romanian standards 13343, 13386, 13387, 13388 for wastes management

A series of stipulations in the field of cleaning up the polluted sites and of the underground waters are included in different laws having an economic, privatizing or commercial character.

With the aim to supplementing and perfecting the legislative frame the Ministry of Waters, Forests and the Environmental Protection has drawn up a packet of regulations that are to be approved by the Parliament or the Government:

- Bill regarding the setting up of the National Fund for the Environment.
- Bill regarding the wastes conditions (regulations)
- Governmental Decision Bill for controlling the wastes import, export and transit.
- Governmental Decision Bill for treating the responsibilities referring to asbestos.
- Governmental Decision Bill for treating the responsibilities referring to PCB using.
- Bill of the MAPPM regarding the compliance programs.
- Bill of the MAPPM regarding the instructions for remedying the soil and the underground waters.

Starting with this year the Romanian Government has taken the decision of elaborating the National Strategy for Sustainable Development meant to establish the priority directions of action, at national level, for the sustainable development of the country along a medium and long term.

According to the principle " polluter pays " the decontamination costs for the soil and the underwater are incumbent on who produced it or in case of estate transfer, the costs are subject for negotiation between the vendor and the buyer. In case of closing up the activity of a state enterprise the clean up costs are taken over by the public debt.

2. REGISTRATION OF CONTAMINATED SITES

The Ministry of Agriculture is making the studies for the soil quality without any particular interest for identifying and recording of the contaminated sites. In 1975 there has been set up The National Integrated System for the Soil Quality, harmonized with EU in 1992.

The Monitoring of the quality of underground waters of Romania devolved upon the authorities for the water of Romania but the collected data were not enough for elaborating a fundamental and complete study on the pollution of the underground waters.

In the last years The Ministry of Water, Forests and the Environmental Protection draws up a yearly report regarding the wastes management including the inventory of the characteristics and the quantity of wastes generated at national level as well as the way they are being stored, recycled and/or eliminated. The report is drawn up by The Bucharest Institute of Research and Environment Design (ICIM) according to the statistics offered by the agencies for the Environmental Protection and the National Institute of Statistics.

The industrial activity represents the main source of wastes and generates the biggest number of polluted sites in Romania. According to the last Report, the industrial wastes in a quantity of 209 million tons represents about 95 % of all the wastes generated in Romania in 1997.

Table 1. Types of wastes (million tons)

Mining solid wastes	Slag and ashes	Metallurgical wastes	Industrial sludge	Chemical wastes	Toxic and hazardous wastes
169.8	11.2	2.9	1.4	1.1	1.6

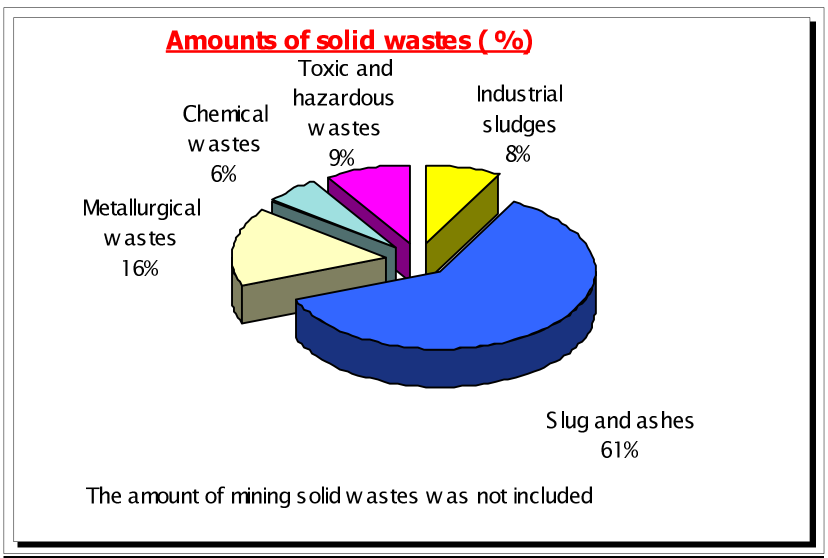
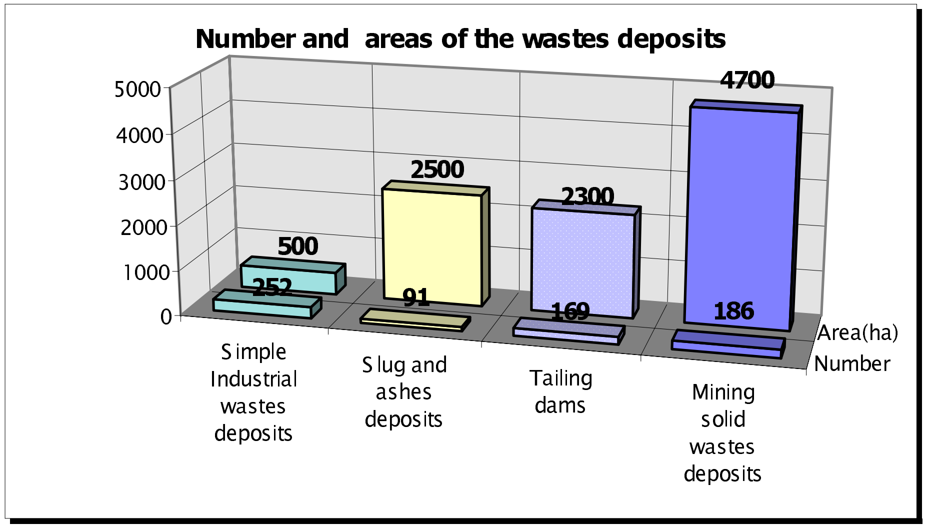


Table 2. Industrial wastes deposits

Deposit type	Number	Area (ha)
Tailing dams	169	2,300
Mining solid wastes deposits	186	4,700
Slug and ashes deposits	91	2,500
Simple industrial wastes deposits	252	500



The total number of registered deposits in the ICIM database is 970 out of which 712 are deposits of industrial wastes that cover an area of over 10,000 ha. Up to this date there has not been drawn up a National Register of Contaminated Sites but an evaluation of ICIM for Harvard Institute for International Development (1998) estimates a number of 1639 sites contaminated covering a total area of 164.254 ha. To this there can be added a number of some thousands of sites polluted with oil-products covering areas from about square meters and tens of hectares.

The quality of the underground waters is monitored by 2,000 hydrogeological bore holes as part of the National Hydrometric supervision network. To this there can be added 12,000 watching points:

1. Hydrogeological bore holes for the observation of the pollution in the contaminated sites
2. Exploitation drillings for water supply
3. Water wells located in rural areas

There has been estimated that in the areas with waste deposits the underwater is polluted mainly due to the inadequate isolation of the sites. The present information obtained by ICIM is not enough for a perfect unitary global evaluation of the quality of underground waters in Romania.

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3. TECHNOLOGY DEVELOPMENT PROGRAM

In 1998 there has been set up The National Committee for Sustainable Development's an intergovernmental structure intended to elaborating a national strategy for sustainable development that also includes among its tasks the wastes management and the cleaning of the contaminated sites. The sectoriale politics in this field are coordinated by the Ministries in whose activities there exist such problems.

The coordination of the activity of research and technological development devolves upon The National Agency for Research and Technology. The technological development is assured by the national institutes on fields of activity under the co-ordination of the Ministries or the independent research institutes. The strategy for the Environmental Protection in Romania includes the elaboration of a unitary program of technological development in the field of decontaminating the polluted sites that has not been finished yet.

4. REMEDIAL METHODS IN USE

During the recent years and mainly after the coming out of the Law on the Environmental Protection there has been made ample actions for solving the problems regarding the decontamination of the polluted sites. The most frequent methods are:

- on site isolation - most frequent
- excavation and soil removal
- natural attenuation
- reactive barriers for petrochemical soil and underground waters pollution
- pump and treat (chemical and biological treatment)

The historical pollution, of long standing, without any intervention along the last years supposes high costs for decontamination activities on a large scale of the polluted sites. The methods used up to this moment are applied on a relatively small scale and mainly in the regions with strong accents of pollution.

5. RESEARCH AND DEVELOPMENT ACTIVITIES

The activity of Research and Development is sustained by the Ministry of Waters, Forests and the Environmental Protection through the Institute of Research and Environment Design and also by other ministries or national companies together with other institutes specialized in fields with an impact upon the environment.

Such research centers exist at the Ministry of Industry and Trade (metallurgy, electric power, mining, chemistry, Syderurgy), The Ministry of Agriculture, The Ministry of Public Workings and Planning , The National Agency of Research and Technology, The Oil National Company , The Coal National Company, and another series of independent institutes and universities.

The companies responsible for decontaminating the polluted sites resort to technologies existing in Romania, ask for achieving adequate technologies to the existing situations or import such technologies. The Romanian research activities in this field are directed towards finding new cost-effective methodologies for decontamination and aim at all known techniques:

- pump and treat (heavy metals, cyanides, phenols, VOCs, SVOCs) physicochemical and biological treatment
- site isolation
- bioremediation
- vapour striping
- other

The Ministry of Waters, Forests and the Environmental Protection of Romania has concentrated lately on inventorying and monitoring the contaminated sites and in the near future the databases will be constituted containing verified and accessible decontaminating technologies as well as of the polluted sites at national scale.

6. CONCLUSIONS

1. The problem of decontaminating the polluted areas is of high priority in the Government policy.

2. There exist the necessary minimum legal frame even if this one has been recently structured in order to be able to determine actions in this sense.

3. The research and the development of the technologies for decontaminating of the pollutes sites has an ascending

4. The costs of using decontaminating technologies are still very high for Romania.

5. The cooperation between Romanian and foreign experts is necessary in order to use decontaminating cost-effective technologies.

SLOVENIA

INTRODUCTION

The situation of environmental protection has not changed substantially over the last year; however, some new documents drafted by the responsible ministry were presented to the public. In 1998 and 1999, some documents, envisaged to address the situation of environmental protection in an overall manner, were sent for public discussion:

- Environmental Situation Report for 1996, published in 1998;
- Strategic Guidelines of the Republic of Slovenia for Waste Management;
- National Environmental Protection Programme, published in December 1998.

These documents have yet to be adopted and verified in parliament, therefore their application is not yet legally binding. Today I will briefly present these three documents, as well as specific obstacles that may hinder their practical implementation in the near future.

1. ENVIRONMENTAL SITUATION REPORT

The 1996 Environmental Situation Report was published as late as the end of 1998. It is almost impossible to understand that it took this long for the responsible services at the Ministry of the Environment, which are bound by law to draft such reports on an annual basis, to collect, edit, prepare and process data on the environment. It took as long as two years for the report to become ready for printing, during a time when the environmental situation appears to be disastrous, calling for immediate measures for improvement. On the other hand, the delay is understandable, since the government currently in office appears to express no particular interest in investing large amounts of money in environmental protection. Regardless of the delay, it needs to be said that the report sets out the situation in exceptional detail, and it is accompanied by all data relevant to the assessment of the environmental situation, thus giving a realistic reflection of this situation.

The report has several chapters on the following topics:
- information on the environmental situation and public involvement,
- research in support of environmental protection,
- environmental control,
- economic instruments in the field of environmental protection,
- planning instruments for the protection of the environment,
- air,
- water,
- soil,
- nature and biodiversity,
- natural resources – mineral raw materials,
- urban environments,
- environmental health conditions,
- waste,
- nuclear safety and radioactivity,
- environmental disasters,
- the driving forces behind releases into the environment and
- environmental issues.

At this point I would like to provide a few illustrative examples from the report; these concern air, water, environmental protection control and waste.

1.1. Air

In Slovenia, probably the largest amount of attention and care was dedicated to the measuring of air pollution and the elimination of emissions; the situation in this field was comparatively good even in the past and has further improved over recent years. The ANAS system (analytical supervisory and alert system) was set up several decades age to measure levels of air pollution. This system has been suitably upgraded over recent years.

The readings of SO_2 and fume concentration levels are taken 24 hours a day in all sizeable towns throughout Slovenia. **Table 1** shows in how many locations readings were taken for individual pollutants in the 1990-1996 period.

Table 1: Number of air pollution control locations in Slovenia

Parameter	1990	1993	1994	1995	1996
SO_2	13+55	21+61	22+59	20+59	20+59
NO_x	5	5	6	7	8
CO	2	2	3	3	3
Ozone	5	5	6	6	8
Total airborne particles	1	1	2	4	7
Fumes	55	61	59	59	59
EMEP net	-	1	1	1	2
GAW net	-	1	1	1	2

Sulphur dioxide
The reduction in concentrations of SO_2 in the air is the result of the switch from the use of coal to natural gas for heating in all sizeable towns; where coal is still in use, imported varieties with lower sulphur content are used. Only in some of the control locations was the maximum permissible concentration of SO_2 exceeded for several hours (MPC is 250 $\mu g/m^3$, and the recommended concentration between 40 and 60 $\mu g/m^3$, which is the arithmetic average of daily averages for one year).

Carbon dioxide
Slovenia has ratified the UN Framework Convention on Climate Change (UN FCCC). Until 1996, CO_2 emissions were declining, but after 1991 they started to increase slightly, as seen from **Table 2**. The table also supplies data on CO_2 emissions by industrial branch in shares. The field is now also regulated by the Decree on Taxes on Releasing CO_2 Emissions into the Air (Official Gazette of the Republic of Slovenia. no. 68/96) whose aim is to reduce CO_2 emissions by an average of 8 per cent between 2008 and 2012, as set by the 1997 Kyoto Protocol, which has also been signed and ratified by Slovenia.

Table 2: CO_2 emissions (in thousand tons) and shares (%) by main branches, 1986 – 1996

Branch	1986	1990	1991	1992	1993	1994	1995	1996
Energy production*	8833 56%	7376 52%	7376 56%	7713 57%	7828 56%	7701 54%	8046 54%	8657 54.7%
Transport	2678 17%	3429 24%	2968 22%	3122 23%	3699 27%	4138 29%	4454 30%	5061 32%
Industrial burning	3543 23%	2726 19%	2310 17%	2119 16%	1740 13%	1996 14%	1707 12%	1546 9.7%
Technological processes	608 4%	641 5%	600** 5%	570** 4%	540** 4%	520 3%	533 4%	562 3.6%
Total	15662	14172	13254	13524	13807	14335	14740	15826

* Thermal plants, heating plants, boiler rooms and small fireplaces
** CO_2 emission from technological processes for 1991, 1992 and 1993 estimated on the basis of data for 1990 and 1994/95.

Nitrogen oxides (NO_x)
Air pollution caused by nitrogen oxides is not a problem, as in 1996 the maximum permissible concentrations were not exceeded at any of the control locations. It has been noted, however, that NO_x emissions are increasing steadily. In 1995, emission levels fell slightly as a result of the increased use of catalytic converters in motor vehicles. **Table 3** provides data on the levels of the main air pollutants: SO_2, NO_x, CO, CO_2, for 1994, 1995 and 1996.

Table 3

	SO_2 t/year	NO_x t/year	CO t/year	CO_2 10^3t/year
1994	176.514	65.924	92.846	13.836
1995	119.301	66.591	91.427	14.208
1996	109.689	70.144	95.371	15.107

Volatile hydrocarbons VOC
The measuring of the levels of these compounds in the air was begun in 1995. It has become clear that applicable legislation is very inadequate, as the maximum permissible concentrations are extremely high - for toluene, for example, it is set at 1 mg/m^3. In 1996, it became clear that in the capital of Slovenia the concentrations of these compounds were between 8 and 11μg/m^3, which is higher than the maximum concentrations permitted in western European countries.

Volatile hydrocarbons NMVOC (not including methane)
In 1990, NMVOC emissions amounted to 35,000 tons. The objective pursued by Slovene legislation is, by 2000, to reduce this amount by around 30 per cent in comparison to 1990, which is going to be difficult to achieve.

Ozone
In summer the concentration levels for this particular pollutant often exceed the maximum permissible concentrations, especially in settlements (the recommended level is 65 μg/m^3 in 24 hours).

Ozone layer protection
Over recent years Slovenia has made a shift for the better in this area with the signing and ratification of the Montreal Protocol and its London Addition. Slovenia does not produce any ozone-depleting substances, but it imports from the EU. In 1994, the government adopted a programme for discontinuing the use of ozone-depleting substances and some of factories have already replaced CFC, 1,1,1-trichloroethane and HCFC in their production of cooling and air-conditioning appliances. The consumption of these substances fell by more than 80 per cent in comparison to 1986.

1.2. Water

Most of the decrees and regulations adopted in recent years concern water protection. The legislator's main objective with these acts is to protect water sources and at the same time ensure that all polluters pay a tax for polluting water. In recent years probably the most progress was made related to the care for the quality of all types of water sources, as the legislator became aware of the importance of this basic natural resource. All bodies of water are protected by law and any commercial exploitation requires a concession, which is granted by the government. A permit must also be obtained to use water for any other purpose.

The report gives a picture of the condition of water by individual segments and supplies data on the release of substances into the water and water consumption by all types of activities.

Quality of groundwater

The quality of groundwater is monitored twice a year at 84 locations which are distributed throughout all 15 plains containing groundwater. The water is assessed according to EU guidelines with which Slovene legislation has been harmonised (Official Gazette of the Republic of Slovenia, no. 46/97). The main groundwater contaminants include nitrates, heavy metals, pesticides and volatile organic compounds (VOC).

Nitrates: in 1996, concentrations of nitrates in excess of 50 mg NO_3/l, which is still permissible according to the Drinking Water Act, were established in four of the plains with groundwater. These were mostly situated in areas subjected to heavy use of artificial fertilisers.

Heavy metals: if we use the MPCs from EU directives, the maximum permissible concentrations for metals were exceeded in around 12 per cent of all groundwater samples collected in 1996 – **Table 4**. The most frequent offenders were zinc (in 15 cases), copper (1 case), six-valence chrome (2 cases) and mercury (1 case).

Table 4: MPC for heavy metals in drinking water

	Official Gazette of the R of Slovenia No. 46/97	**EU Directive 80/778/EEC**
	MPC	**MPC**
Cu µg/l	2000	-
Zn µg/l	3000	-
Cd µg/l	3	5
Cr (III) µg/l	50	50
Cr (VI) µg/l	50	-
Ni µg/l	20	50
Pb µg/l	10	50
Hg µg/l	1	1

MPC - Maximum permissible concentration
RC – Recommended concentration

Pesticides: according to the rules (Official Gazette of the Republic of Slovenia, nos. 46/97 and 52/97) the total concentrations of all pesticides in drinking water may not exceed 0.5 µg/l or 0.1 µg/l for an individual pesticide. According to the report, these values were exceeded in 30 per cent of all tests and analyses carried out. Water was analysed for 27 pesticides and their metabolites in common use. Between 1992 and 1996 a fall in the concentration of pesticides in groundwater was observed, as seen from **Table 5**. The maximum permissible level was most frequently exceeded by the pesticide atrazine. This pesticide was most often found in groundwater in the areas of intensive farming practices and where excessive amounts of chemical substances had been used. In addition to atrazine, the most common pesticides exceeding the limits included metalochlorine compounds and dieldrin.

Table 5: Pesticide levels in groundwater in Slovenia in 1992, 1994, 1995 and 1996
Pesticide levels

	No.of sampling locations	Sample below MC*(%)	Sample below MC*(%)	Sample below MC*(%)	Sample below MC*(%)
Groundwater		**1992**	**1994**	**1995**	**1996**
Prekmursko.-Apaško polje	7	29	29	28	35
Mursko polje	3	67	82	100	100
Dravsko polje-Vrbanski plato	10	18	45	41	36
Ptujsko polje	4	25	63	25	37
Sp.Savin.dol.-dol.Bolske in Hudinje	11	36	57	65	71
Kranjsko polje	4	71	100	100	100
Sorško polje	9	89	94	94	100
Dol.Kamn.Bist Vodiško polje	7	53	50	50	57
Ljubljansko polje in Barje	11	100	95	100	100
Bre• iško-• ateško polje	5	100	100	90	100
Krško polje	8	93	69	81	100
Vipavsko-Soška dolina	4	100	100	100	100
Slovenija	**83**	**63**	**68**	**70**	**77**

Pesticide levels

	No.of sampling locations	MC (µg/l)	MC (µg/l)	MC (µg/l)	MC (µg/l)
Groundwater		**1992**	**1994**	**1995**	**1996**
Prekmursko.-Apaško polje	7	3.83	2.16	1.83	1.55
Mursko polje	3	0.55	0.59	0.34	0.26
Dravsko polje-Vrbanski plato	10	5.06	19.95	4.41	3.20
Ptujsko polje	4	2.17	1.44	2.34	2.17
Sp.Savin.dol.-dol.Bolske in Hudinje	11	1.80	0.95	0.63	0.74
Kransjko polje	4	0.73	0.27	0.14	0.31
Sorško polje	9	2.18	0.55	0.82	0.30
Dol.Kamn.Bist Vodiško polje	7	4.66	3.17	2.70	1.69
Ljubljansko polje in Barje	11	0.27	0.61	0.33	0.45
Bre• iško-• ateško polje	5	0.40	0.35	0.52	0
Krško polje	8	0.50	1.04	0.81	0.48
Vipavsko-Soška dolina	4	0.29	0.05	0.05	0.05
Slovenija	**83**				

Atrazine levels

	No.of sampling locations	MC** (µg/l)	MC** (µg/l)	MC** (µg/l)	MC** (µg/l)
Groundwater		**1992**	**1994**	**1995**	**1996**
Prekmursko.-Apaško polje	7	1.30	0.80	0.85	0.58
Mursko polje	3	0.20	0.25	0.12	0.08
Dravsko polje-Vrbanski plato	10	2.10	7.30	1.30	1.64
Ptujsko polje	4	1.10	0.49	0.82	0.66
Sp.Savin.dol.-dol.Bolske in Hudinje	11	0.77	0.23	0.52	0.74
Kransjko polje	4	0.40	0.15	0.13	0.20
Sorško polje	9	1.50	0.25	0.21	0.16
Dol.Kamn.Bist Vodiško polje	7	0.82	0.56	0.47	0.34
Ljubljansko polje in Barje	11	-	0.57	0.32	0.40
Bre• iško-• ateško polje	5	0.20	0.10	0.24	0
Krško polje	8	0.30	0.19	0.13	0.24
Vipavsko-Soška dolina	4	0.20	0	0	0
Slovenija	**83**				

Footnote:
* MPL for pesticides in total is 0.5 µg/l
** MPL for atrazine is 0.1 µg/l
Source: Ministry of the Environment and Physical Planning, Hydrometerological Institute

Volatile organic compounds (VOC): the maximum permissible concentrations for chlorinated organic solvents and some aromatic compounds in particular were exceeded in 16 cases, according to EU standards (the permissible level for an individual solvent is 1 µg/l). The most likely source of this type of groundwater pollution is a discharge of untreated local industrial wastewater.

Quality of water sources
Biological and chemical parameters of water sources are analysed when the need arises. At least 15 of the most important sources are analysed annually. The water sources which are situated on karstic ground are especially vulnerable to contamination, as it is well-known that the self-purification abilities of these areas are poor. The analyses of such sources showed that water sources in the karst area were contaminated in some places with phenolic compounds, polycyclic aromatic hydrocarbons, heavy metals and mineral oils. In two of the locations, the presence of organophosphorous compounds was established.

Quality of running surface water
The monitoring of running surface water for quality includes the following:
- physical and chemical analysis and biological analysis,
- saprobiological analysis,
- testing for 7 metal in water, suspended in particles and in the sediment,
- testing for organic compounds in water, namely: phenols, pesticides, polycyclical aromatic hydrocarbons, BFC, GC/MF picture.

Monitoring is performed at approximately 100 sites between two and six times a year. The number of readings and the analysis depends on the pollution levels and on the importance of the particular water stream. The analysis is carried out in accordance with EU regulations and the WHO Recommendations for Drinking Water. Based on the results of the analysis, water is then classified into one of the following four categories:
- 1st category of water which, according to the WHO recommendations, is suitable for drinking,
- 2nd category of water which is moderately polluted water and can be made suitable for drinking following treatment by appropriate methods,

- 3rd category of water which is not suitable for any use,
- 4th category of water from heavily polluted streams.

There are five streams in specific areas that fall into the fourth category of being heavily polluted and unsuitable for any use.

Quality of lakes

Regular monitoring of lake water takes place only at the three largest lakes. In addition to the monitoring of lake water, all their tributaries and outflows are regularly monitored. The water in all three lakes is comparatively clean and has been improving in recent years, following the construction of purification plants on their tributaries.

Quality of sea water

The Slovene coast, which is situated in the northern part of the Adriatic Sea, is only 45 km long. This section of coast is part of the Gulf of Trieste, which is heavily polluted. Slovenia has signed and ratified three important protocols on the protection of the Mediterranean Sea, as follows:

- Protocol on Protecting the Mediterranean Sea from Land Pollution,
- Protocol on Cooperation in Fighting Against Pollution of the Mediterranean Sea by Oil and Other Dangerous Substances in the Event of an Accident,
- Protocol on Special Protected Areas in the Mediterranean Sea.

The sea is mainly polluted with nitrates, phosphates, carbohydrates and heavy metals. Monitoring runs throughout the year.

Table 6 provides a comparison of the inputs of some pollutants into the coastal sea, based on assessments for the 1983-1988 and 1989-95 periods.

Table 6: Comparison of the overall input of some pollutants in the coastal sea, assessed on the basis of data on river input and waste for the 1983-1998 and 1989-995 periods

Pollutant Quantity	1983-1988 period t/year	1989-95 period t/year
suspended particles	6324	7002
carbon, total	1094	1075
phosphorous, total	172	134
detergents	46	60
Mercury	0.06	0.04
Cadmium	0.69	1.40
Lead	1.26	18.89
Chrome	10.51	2.13
Zinc	1413.0	343.7

Source: Biology Institute at the University of Ljubljana, Piran Marine Biology Station

Releases into water

Most of the releases into the water are caused by municipal and industrial wastewater.

Municipal purification plants are used for the treatment of only about 30 per cent of municipal wastewater; around 45 per cent of municipal wastewater is collected in wastewater reservoirs and 25 per cent is discharged into water streams or the ground without any prior treatment. Only 6 out of 125 municipal purification plants are bigger than 100,000 PE. The rest are smaller, mostly local purification plants of around 2,000 PE.

Table 7 contains data on annual quantities of wastewater (in million m^3) released by industry, mining, electricity production into the ground, the public sewage system and surface waters. The last columns in **Table 7** make it clear why some of the Slovene streams are so heavily polluted with various industrial contaminates.

Table 7: Annual quantities of wastewater (in million m³) discharged by industry, mining and electricity production

Discharged wastewater

Year	Ground	Public sewage system	Surface water
1985	3.9	64.4	804.1
1988	4.3	58.5	738.3
1989	3.9	66.7	764.2
1990	3.6	59.2	693.9
1991	2.1	36.4	785.9
1992	1.7	37.3	613.3
1993	1.4	31.0	596.1
1994	1.4	30.0	762.7
1995	2.6	30.0	733.1

Source: Statistical Office of Slovenia

Water consumption

Water used for drinking is collected mostly from springs. Approximately $30x10^6$ m^3 of water is consumed annually. Most of the water used by industry, which consumes around $150x10^6$ m^3/year, also comes from the springs. The water for farming, approximately $4.5x10^6$ m^3/year, is generally supplied by the accumulation reservoirs. Surface running water is used to generate electricity.

In terms of quantity, Slovenia falls into the group of countries with a fairly abundant water supply. The problem is that water is unevenly distributed and that in some of the surface water streams the difference between the minimum and medium flow is quite large, and as a result there are regions in Slovenia which suffer from water shortages. Slovenia has around 7,000 streams with a mass of water totalling around 63 m^3/sek.

1.3. Environmental control

In 1995, the Inspectorate of the Republic of Slovenia for the Environment and Physical Planning was founded. It consists of two services: Environmental Inspection and Physical Planning Inspection. Environmental Inspection is authorised to conduct the following: supervision of the quality of water and water streams; supervision of the storing of dangerous substances; control of air pollution and noise; supervision of waste and waste disposal sites; supervision of nature protection; supervision of electromagnetic radiation; carrying out various interventions in the event of accidents that may cause environmental pollution; carrying out technical inspections of new investments.
In the opinion of the inspection, the following is required if more effective supervision and an improved overall situation of environmental protection is to be achieved:

- an increase in the number of inspectors, in keeping with the legislation,
- setting-up local environmental inspection or supervisory bodies, in keeping with the law,
- better technical equipment for inspection (cars, phones, computer equipment, etc.).

The most important is the realisation that one of the main reasons for the abysmal environmental situation in Slovenia is poor waste management, which is why the inspection proposed that relevant legislation be immediately adopted, which will empower it to take measures.

1.4. Waste management

The situation of waste management is probably the worst of all the areas where the legislator has devoted its attentions to the environment. In comparison with legal acts that have been prepared and adopted in other areas of environmental protection, in this area the legislation lags behind. The majority of implementing regulations for waste management are very dated; only two instructions and two rules have been adopted in recent years. In spite of the legal obligation the situation has not changed in practice, and waste keeps piling up in various official or even illegal dumpsites. Although the situation is critical, the relevant ministry and the government are not doing enough to regulate the matter.

The amount of waste
Despite some efforts carried out in the past, the amount of waste that is generated annually continues to grow. Each year around 850,000 tons of municipal waste is produced (420 kg/ person). This number includes around 75 per cent of households which are covered by organised waste collection service. **Table 8** shows the quantities for all types of waste and their shares in percent and by branch.

Table 8: Waste by the branch which generated it, 1994

All types of waste in total	8.57 million tons
by agriculture, forestry and food processing	40%
construction waste material	26%
energy sector	14%
municipal waste	10%
industrial waste	10%

Sources: Ministry of the Environment and Physical Planning, Strategic Guidelines on Waste Management, 1996

Waste management
The most common method of waste management is disposal, since Slovenia does not have any municipal or industrial waste incinerators (with the exception of two factories with local incinerators, which are of limited capacity and suffice only for their own needs). Almost all waste is deposited at 53 municipal dumpsites, most of which (at least 70 per cent) will be full within 4 to 6 years. In addition to these, there are also 13 dumpsites for some types of industrial and mining waste. Slovenia has ratified the Basel Convention on Export, Import and Transit of Dangerous Goods and pursuant to this document around 5,500 tons of waste was exported and 21,000 tons imported in 1996.

2. STRATEGIC GUIDELINES OF THE REPUBLIC OF SLOVENIA FOR WASTE MANAGEMENT

As far as its content and the dates it sets, this document is unrealistic, as the dates for some of the activities that should have been carried out by now have already passed.

The document addresses the following groups of issues:
- situation on waste management,
- strategic guidelines and objectives for waste management,
- measures for achieving the objectives,
- identification of bodies in charge of activities,
- developmental scenario and investments,

and finally, a short-term programme for enacting the concept of waste management.

Situation of waste management
The conditions for the handling of waste have been critical for several decades now. The amount of all types of waste is growing from year to year and nearly all types of waste end up in municipal dumpsites, illegal dumpsites and car junkyards. There is little use made of the material or energy potential, even though it would be possible, through selection of waste at the source, to recycle or produce energy from at least 50 per cent of all waste.

Strategic guidelines for and objectives of waste management

This part addresses the issue of waste handling as part of the developmental strategy for the economy, energy sector and agriculture. It envisages a reduction in the amount waste produced, inactivation of waste, immobilisation of dangerous waste, use of material and energy potential of waste. It also sets dates by when individual stages of handling need to be prepared. This is where doubts arise as to how realistic this plan actually is. By 2000 all regulations, decrees and standards are to be prepared and expert administrative services set up to co-ordinate waste handling. It also envisages that within 10 years of implementing the concept of waste handling the amount of waste now deposited at dumpsites will be reduced by around 40 per cent, and within 15 years, by around 60 per cent, and that around 48 per cent of all waste will be used for its material and energy values.

Measures for reaching the objectives

The condition for reaching the set objectives is that key measures, legislative regulations, economic measures, physical planning measures, the protection of natural and cultural heritage, organisational measures and R&D activities are ensured.

The harmonisation of Slovene legislation with the EU regulations should be happening much faster than at present, as practically nothing is being done in this area. The economic measures envisage that money for the funding and handling of waste will be accrued by the state by increasing the costs of household and industrial waste collection, whereby every producer or owner of waste will have to pay full the commercial price for waste processing. The initial funding will be provided by the state from the budget. Nothing has been done in this area in recent years, and that means it will be difficult if not impossible for this strategy to meet the deadlines it sets out.

Identifying the bodies in charge of activities

The body in charge is primarily the relevant ministry (state), then all local communities and commercial activities which create waste.

Development scenario for investments

The scenario envisages such waste handling which is a compromise between the following:

- possible measures for a comparatively rapid and efficient resolution of accumulated problems in connection with waste,
- envisaged guidelines and objectives, in keeping with the trends in other European countries,
- economic ability of Slovene society.

In order to deal with the main issues of handling waste, approximately DM 2 billion needs to be secured for the first stage, just for the initial investments, and an additional DM 100 million for the organisational, administrative and legal objectives.

As far as the dates set out in this paper and the envisaged funding are concerned, they will have to be amended (at least the dates). This is in consideration of the fact that the activities which should now be in their final stages, have yet to started.

3. NATIONAL ENVIRONMENTAL PROTECTION PROGRAMME

The National Environmental Protection Programme was prepared on the basis of the Environmental Protection Act and contains objectives of environmental protection and the rational use of natural goods for a period of 10 years.

The programme’s priority objectives are as follows:

- to improve conditions in water environments,
- to establish modern waste handling techniques,
- to preserve and protect biodiversity and genetic pools,
- to strengthen environmental protection institutions in all areas.

The programme also addresses other objectives, including air, soil and forests, noise, risk, and radiation.

The measures for implementing the national programme include: increased administrative efficiency; research and development; preparation of environmental protection information systems; harmonisation of Slovene legislation with the EU legislation; preparation of economic measures; founding of public services; education and training in environmental protection; encouraging international cooperation.

This project requires enormous funding and the exact costs of its implementation are not yet clear but, according to some predictions, at least DM 500 million a year will be required to carry out the priority objectives.

4. CONCLUSION

These three papers paint a picture of the environmental situation and the legislator's, i.e. the relevant ministry's, desires for change in environmental protection. The only realistic paper, in which all the data is well substantiated, is the 1996 Environmental Situation Report; while the other two, as far as the dates they set are concerned, are nothing but wishes and are a long way from being fulfilled.

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SWEDEN

1. LEGAL AND ADMINISTRATIVE ISSUES

Finally, we now have legislation that covers remedial issues in Sweden. On 1 January 1999 new environmental legislation, the Environmental Code, entered into force. The rules from 15 former acts have been put together. Remedial issues are gathered under chapter 10.

The purpose of this new legislation is to clarify liability and give the authorities greater opportunity to promote, control and steer remedial action. With the new Code, it will be possible to place demands on environmentally hazardous activities that have been performed after 30 June 1969. Liability for remedial costs rests primarily with the party conducting the activity. In the second instance, it is the landowner who is responsible if he, at the time of the purchase of the property, knew about the pollution or ought to have discovered it. The landowners are only responsible for purchases after 1 January 1999. If several activity operators or landowner are deemed responsible, they will normally be jointly liable. The liability for remediation cannot become time-barred.

A party who owns or uses real property must immediately advise the supervisory authority if pollution is discovered at the property. The obligation to provide information also applies even if the area was previously considered to be polluted.

The new legislation also introduces the official registration of confirmed contaminated sites. The county administrative board must declare an area of land or water to be an environmental hazard if the area is so severely polluted that, considering the risk for human health and the environment, it is necessary to lay down limitations on the use of land or other precautionary measures.

In 1997 the Swedish EPA presented guideline values for 36 contaminants in 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 that has been contaminated, intentionally or unintentionally, by industry or some other activity. The definition of "contaminated" is that the levels of contamination apparently exceed the local/regional background values.

After a year, 1998, without any financial means for remedial action, the future now looks considerably brighter. For the following four years, the Swedish EPA will receive SEK 550 million or USD 65 million.

2. REGISTRATION OF CONTAMINATED SITES

So far we have identified about 12,000 potential sites in Sweden. We estimate the total number of contaminated sites to be 22,000. Due to our industrial structure, sites with metallic contaminants dominate. Mines with acid mine drainage represent our heaviest and most costly remedial problem. Other problems are caused by metal works, iron and steel works and surface plating facilities. There is also a group of industries using complex mixtures of metals and persistent organic substances such as chloralkali (Hg and dioxins/furans); these include gasworks, the pulp and paper industry (Hg and PCB) and wood preservation plants (CCA, Cu, PAH, PCP and dioxins/furans).

In addition, there is the petroleum industry with oil refineries, oil depots and gas stations which represent the largest group by number but on the other hand cause the problems which are easiest to solve.

Today we have an unofficial register of identified, suspected sites at the Swedish EPA. This register is 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 to provide a basis for regional planning and the prioritisation 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 authorised 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. TECHNOLOGY DEVELOPMENT PROGRAMME

The Swedish EPA and the Swedish Delegation for Sustainable Technology are running a cooperation programme concerning technological development in the field of site remediation. This programme is to act as a catalyst for the development of new technology in Sweden. It includes a research and development project being carried out at an industrial site in central Stockholm. Stockholm City, which owns the land, is also involved in the project. The site, where tar products were previously processed, is contaminated with PAH and metals. The sediment is also contaminated. The following pilot trials using various treatment methods is being carried out:

- Chemical leaching of metals and organic compounds from the sediment – NCC and Raymond and Irina Swanson (USA)
- Biological slurry treatment of the organic compounds in the soil and sediment -Eko Tec (Sweden)
- Electro-dialysis of metals in the sediment – Jordmiljö Nordic AB and A.S. Bioteknisk Jordrens (Denmark)
- In-situ geo-oxidation of organic compounds in the soil – Jordmiljö Nordic AB (Denmark)
- Thermal evaporation of organic compounds and mercury from the soil, clay and sediment - Cedeka Miljöentreprenad AB, Skanska Anläggningar AB (Sweden)
- Thermal evaporation of organic compounds from the soil, clay and sediment – Ragn-Sells Specialavfall AB (Sweden) and Ecotechnik Bodem GB (the Netherlands)
- Thermal evaporation of organic compounds and mercury from the soil - Green Soil Ltd OY (Finland).
- Soil-washing with the biological treatment of organic compounds and metals in the soil – Gotthard Heidemij Marksanering AB (Sweden, the Netherlands).

The trials are expected to be completed and evaluated by the autumn of 1999.

Another study within the cooperation programme concerns chlorinated organic compounds in soil. The following four methods are being tested at different sites around the country:

- Vapour injection with vacuum extraction – Däldehög AB (Sweden) and Hedeselskapet (Denmark)
- Anaerobic and aerobic degradation – Marksanering i Sverige AB and VBB-VIAK (Sweden)
- Air sparging and vacuum extraction – Rettig värme AB, EkotEc (Sweden)
- Reactive barriers . Bengtsfors Municipality and VBB-VIAK (Sweden)

4. REMEDIAL METHODS IN USE

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, immobilisation 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 kinds of treatment are becoming more and more common. In particular, biological methods like composting and in-situ methods such as vapour extraction and bio-venting 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 the 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 vapour extraction, bio-venting 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 disused petrol stations. 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 vapour extraction and bio-venting.

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. USD 700 million will be spent over 3 years. Local authorities will present plans to the Government, who will prioritise and allocate the funds. The Swedish EPA is not so 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 receive less and less money and temporary organisations, 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 vapour extraction, bio-venting 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 PAH or PCP, a bio slurry reactor is needed.

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

Concerning thermal treatment, we have no experience of full-scale treatment yet but the tests shows that it could be useful for PAH, Hg, dioxins etc.

5. CONCLUSION

Metals and complex mixtures of metals and persistent organic compounds 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, Denmark or Germany.

The new Environmental Code, the remedial programme for gas stations and the Government’s emphatic financial investment totalling SEK 550 million (USD 65 million) over the next four years will no doubt impart incisive momentum to both the market and technological development.

SWITZERLAND

1. LEGAL AND ADMINISTRATIVE ISSUES

The political structure of Switzerland is federalist and organised by 26 local authorities, called Cantons. Political authority for conservation is vested in the Department of the Environment, Traffic, Energy and Communication. The Swiss Agency for the Environment, Forests and Landscape, as part of this ministry, is responsible for preparing laws, ordinances and technical guidelines, and for providing public information. Environmental protection is implemented by the Cantons by means of emission controls, e.g. in the areas of waste management, hazardous substances and air pollution control.

Ordinance relating to the remediation of contaminated sites

Based on the Federal Law relating to the Protection of the Environment, amended in 1995, the Ordinance relating to the remediation of contaminated sites (in force since 1 October 1998) regulates their identification, assessment and remediation. Implementation of this Ordinance is not at Federal Government level but is assigned to the Cantons, because of their greater proximity to the environmental problems in question. The Federal Government implements the Ordinance directly only where areas of Federal interest are concerned, e.g. military sites, railway installations or airports. This ensures a systematic approach to the assessment and remediation of contaminated sites throughout the country. Up until now remedial activities have concentrated on urgent cases, often discovered in the course of redevelopment.

Swiss Government policy has the following objectives for contaminated sites:

- Stopping emissions at source
- Cooperation between polluters and authorities
- Legal equality trough harmonised criteria
- Prevention of new risks.

Ordinance relating to the financing of the remediation of contaminated sites

According to current estimates, the registers of sites polluted by waste will eventually contain 40-50,000 sites. About 3,000 of these are likely to require remediation carried out within the next 20 to 25 years. The overall costs will be more than 3,000 million ECU (5,000 million Swiss Francs).

In spite of the clear regulations covering identification, assessment and remediation in the Ordinance relating to the remediation of contaminated sites, there is a danger that considering the high costs, the necessary remediation of large contaminated sites are not tackled, but will be left to future generations to deal with. Remediation should not be provoked by development, building activities or the presence of enough money; the main criterion should be the actual hazard presented to the environment. It is the Confederation's aim that contaminated sites representing a severe potential danger be rapidly remediated.

In many cases, the person responsible for making remedial action necessary in the first place can bear little or nothing of the remediation costs. The remaining costs, estimated at 1,200 million ECU, have to be carried by the Cantons and thus by public taxes. A draft of a fiscal instrument (Ordinance) has been elaborated in order to give the Cantons financial support.

An amendment (article 32e) to the Federal Law relating to the Protection of the Environment set out the basic framework for the Ordinance relating to the financing of the remediation of contaminated sites. The Department of the Environment, Traffic, Energy and Communication has initiated the procedure of consultation for this new Ordinance. The tax is to be levied on the deposition of wastes and takes into account the various types of landfill. The rate is limited to a maximum of 20% of the average disposal costs. The revenue is expressly dedicated to financing remediation, and flows to the Cantons if:

- Contaminated sites (landfills, industrial sites or sites of accidents) are to be remediated where the polluter cannot be identified or is unable to pay; or
- Landfills are to be remediated on which a significant proportion of the wastes were municipal.

Payment by the Confederation is limited to 40% of the remediation costs.

The estimated remediation costs borne by the Cantons will require annual funds of around 20 million ECU.

Switzerland is not the only country with a fiscal instrument to fund remediation of contaminated sites. The experience of other countries demonstrates that having to pay a charge for depositing wastes in a landfill is useful in connection with contaminated sites. A charge on oil, derivatives of oil or basic chemicals is not appropriate for Switzerland. Furthermore it has been shown to be most successful to use the money exclusively to finance the remediation of contaminated sites, and not for the support of technologies, employees or lawsuits.

2. REGISTRATION OF CONTAMINATED SITES

In order to identify the small number of dangerously contaminated sites (~3,000) within the larger number of polluted sites (40-50,000) a step-by-step investigation is required. First the Cantons must draw up a register of sites polluted by waste, distinguishing between landfills, industrial and accident sites. These registers will be made available to the public and must be completed by the Cantons by the year 2003. The registers will be updated continuously, and the registered sites are prioritised in order to decide which should be investigated most urgently. Sites that are completely decontaminated will be deleted from the register.

The owner of a polluted site is obliged to undertake a historical review and technical site investigation based on a program approved by the authority. In order to determine whether there is a need for remediation or monitoring, or if no further action is necessary, the authority must consider both emissions from the site and harmful effects to the environment.

A decision to take remedial action will require a site-specific risk analysis based on interactions between the site and the environment (mainly groundwater, surface water, soil and air) and taking into account transport potentials and barriers. Intervention values for leachates and air have been elaborated, based on human toxicological considerations, and consistent with the relevant laws concerning water and soil.

No further action is necessary as long as no immissions are detectable and the actual and possible emissions are below the intervention values. Remediation is required if the actual and possible emissions exceed any intervention value and if no long-term retention is guaranteed. Remediation is also needed if immissions can pollute surface water or groundwater of public interest. In other cases only monitoring is required.

The general objective of remediation is to remove the need for further remediation following the clean-up. However, other criteria such as technological feasibility, ecological sustainability and the costs of any remedial action must also be considered. Sites cannot always be returned to their natural state. Sometimes the target criteria only guarantee the protection and maintenance of the affected environmental media in their current use.

3. TECHNOLOGY DEVELOPMENT PROGRAM

The Federal Law relating to the Protection of the Environment enables the Swiss Agency for the Environment, Forests and Landscape to support in the future the development of new technologies in all environmental fields. For this extended assignment 2 to 2.5 million ECU are available annually. The development of installations, treatment methods and technologies to reduce pollution are particularly favoured. The support is not restricted to certain treatment methods, e.g. recycling technologies, but is available to all environmental areas.

At the moment there are 3 specific projects for the remediation of contaminated sites that are under consideration for finance from this fund. In two of these projects the use of permeable reactive barriers are being investigated as a remedial method; the contaminants are in one case chlorinated solvents and in the other chromium. In the third project the treatment is an *in situ* bioremediation of a site contaminated by mineral oil.

4. REMEDIAL METHODS IN USE

The predominant remedial method in the approximately 200 remediations so far carried out is the excavation of the contaminated material followed by containment of the site. However, less well-known remedial technologies, particularly *in situ* measures, are becoming more acceptable.

Recently a practically-oriented database for the treatment of contaminated sites was created by the Swiss Agency for the Environment, Forests and Landscape. This information system is called IUVA and contains details of remedial methods as well as data on companies such as remediation specialists and consultancies, administrative authorities and associations. The database will be complemented with research and development activities. In addition, IUVA has a list of harmful substances with supplementary information relevant to contaminated sites (intervention values). Thus, based on the pollution level of a contaminated site, a user of the IUVA can obtain information on potential remediation companies, suitable remedial methods, or examples of analogous cases.

5. RESEARCH AND DEVELOPMENT ACTIVITIES

A program of scientific research into the investigation, remediation and validation of contaminated sites has been initiated. Most of the roughly 60 research projects are carried out by the Federal Technical Institutes in Zürich (ETHZ) and Lausanne (EPFL). Universities and cantonal laboratories also have various projects. Many of the projects are financially supported by the Swiss National Science Foundation (NSF), by other national institutions or by the Cantons. A few are funded by private companies. Additional information on the Swiss research projects can be found on the CARACAS website.

6. CONCLUSIONS

Current Federal policy on the treatment of contaminated sites is guided by the following important principles:

- Goals for the treatment of contaminated sites should be uniform and valid throughout Switzerland.
- The authorities work with those directly affected, especially with industry.
- The contaminated sites should be treated according to objective urgency (hazard to the environment).
- Remediation should be carried out rapidly using realistic solutions (principle of commensurability); the search for perfect solutions, thereby leaving the problem for future generations, must be avoided.
- Remediation requirements should as far as possible be set according to the environmental situation at the time.
- The remediation should guarantee a permanent stop to illegal effects, and ensure that the measures are sustainable overall.
- Future contaminated sites should be avoided by the 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 which makes environmentally legitimate treatment of contaminated sites possible, and which also ensures that these regulations are acceptable to the population and to those affected by the remediation.

The registration of sites contaminated with waste is valuable. On the other hand there is still a great need to investigate the sites and their possible remediation, which can in some cases be very cost-intensive.

Prerequisites must be established so that investigation, and if necessary remediation, can be carried out not just under pressure from plans for construction, but where it is necessary for purely environmental reasons. We hope that the planned Ordinance relating to the financing of the remediation of contaminated sites will provide significant support to this aim.

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 3 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 İzmit 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, that is within the first 300 m of the reservoir shore called "*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 20300 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 3000 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.

- **İncirlik 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 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 %) 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.

- **Chromium Ore Processing Residue Dump Site**: At two of these sites, 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, CORP is dumped at a temporary dump site near factory. The unprocessed row chromite ore ($FeCr_2O_4$) contains nearly 45 % 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.

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. The number of soil and groundwater remediation research projects supported financially by the Turkish *State Planning Organization* and other governmental institutions is increasing. For example, a project regarding the performance assessment of solidification/stabilization (S/S) technology for remediation of a large group of wastes (e.g., soils, mining residue and paper and pulp industry sludge) containing organic contaminants (PCB and AOX) and heavy metals has been initiated. 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. This year the General Directorate of State Hydraulic Works has initiated two pilot projects to update hydrogeologic investigations of two major groundwater basins. The main objectives are to develop comprehensive data base and appropriate groundwater management plans using recent technologies such as GIS, RS and advanced numerical groundwater modeling and to set the standards for similar studies for the other major basins.

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 a 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 (17 per cent) but it represents a significant portion (27 per cent) 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 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

This paper is intended to be an update to the Tour de Table paper at the Vienna Meeting of the Pilot Study in February 1998.

1. LEGAL AND ADMINISTRATIVE ISSUES

At the previous meeting the Tour de Table paper presented the background to UK policy on land affected by contamination and a description of the "contaminated land provisions" of Part IIA of the Environmental Protection Act 1990 (as introduced by section 57 of the Environment Act 1995). Part IIA of EPA'90 is modelled on the existing statutory nuisance provisions and will replace them in respect of contaminated land.

In July 1998 the UK Government announced the outcome of its Comprehensive Spending Review and its implications for the Environment Protection Programme of the Department of the Environment, Transport and the Regions (DETR) and the Scottish Office. The Government pledged to bring into force Part IIA of EPA '90 in the summer of 1999 and made available additional resources to local authorities and the environmental agencies (i.e. the Environment Agency and the Scottish Environment Protection Agency) to assist implementation of the new regime. In total £55.7 million over the next three years was made available to local authorities in England, Scotland, and Wales to develop their inspection strategies, carry out site investigations and take forward any enforcement action. The Government also announced that £47 million was to be available to local authorities and the environmental agencies to tackle remediation of orphan sites.

2. TECHNOLOGY DEVELOPMENT PROGRAMMES

In 1998, the Government also announced the launch of the CLAIRE initiative (Contaminated Land: Applications in Real Environments) [1]. The objective of CLAIRE is to establish a network of test sites to research and demonstrate cost-effective techniques for the investigation and remediation of land affected by contamination in the UK. CLAIRE has the backing of a consortium of UK stakeholders including Government, regulators, the research community, and industry. CLAIRE will be funded by a group of industrial and public sector partners who will provide core funding for the organisation. This will be supplemented by project fees, charged as appropriate to the different groups who operate projects on CLAIRE sites.

The need for CLAIRE arises from two important factors:

- The increasing pressure to reduce the amount of "greenfield" land used for development in the UK. One solution is the re-use of "brownfield" sites, abandoned urban and commercial land that is currently derelict, and in many cases also potentially contaminated.
- Pressure on the conventional approaches to remediation of land contamination such as excavation and disposal to landfill through developing legislation and policy and increased cost. Despite this, the use of many process-based technologies remains low, primarily because of the perceived high cost of such treatments and concerns about their technological risk.

CLAIRE aims to address the key issue of how to get over the information barrier limiting the use of process-based remediation technologies in the UK. The requirement is to understand the impact of contamination and demonstrate the practical application of cost-effective but sustainable solutions that extend the range of sites for which treatment is feasible and reduce the technological risk involved. This requires research, development and demonstration of treatment technologies at a field-scale, comparing the effectiveness of the treatment against natural processes, and then disseminating information about the approach to a community of relevant stakeholders.

CLAIRE will establish a network of independently owned test sites, which will be representative of land contamination in the UK. CLAIRE will facilitate the use of this network by independent projects that either demonstrate the application of specific technologies to these sites, or research new approaches that may offer improved remediation solutions. CLAIRE will collate, analyse and disseminate the information resulting from these projects.

3. REMEDIAL METHODS IN USE

For a number of years the anecdotal evidence has pointed to the fact that the UK land remediation market is dominated by conventional engineering approaches, mainly excavation and disposal, mixing/regrading, in-ground barrier and cover systems. However, there is also increasing evidence of the uptake of process-based technologies such as *ex situ* bioremediation (mainly biopiles) and *in situ* techniques such as soil vapour extraction, air sparging and their bioremediation counterparts.

There have been several studies looking at the use of remedial approaches in the UK [2,3,4]. However, none of these have attempted to collect information across the wide spectrum of the land remediation market, focusing on the economic market worth of the companies involved and not the particular reason for/types of strategy implemented.

In January this year, the Environment Agency launched a project looking to survey the remediation market over the last three years in order to provide a detailed snap-shot of the current commercially available techniques and the situations in which they are/are not used. The Agency expects the survey to be completed in the autumn 1999.

Research and Development Activities

Table 1 lists a number of completed, on-going, and proposed R&D projects related to the remediation of land affected by contamination funded by the environmental agencies and the research councils.

Table 1: Recent UK R&D Projects on remediation of land affected by contamination (not intended to be inclusive).

PROJECT	**STATUS**
RESEARCH COUNCILS	
Assessment of *in situ* bioavailability of heavy metals and impacts on the bioremediation of persistent organic pollutants in soil	Funded by BBSRC at the University of Aberdeen. Three year study (1/97 until 1/00). Part of Environmental Biotechnology Programme.
Cyanide biodegradation: a model for the development of molecular probes for optimisation of bioremediation	Funded by BBSRC at the University of Oxford. Three year study (11/98 until 11/01). Part of Environmental Biotechnology Programme.
Investigating novel xenobiotic-metabolising p450 in *Phanerochaete chrysosporium*: a white-rot fungus used in bioremediation	Funded by BBSRC at the University of Aberystwyth. Three year study (5/98 until 5/01).
Penetration of dense non-aqueous pollutants into deep Triassic sandstone aquifers	Funded by EPSRC/NERC at the University of Sheffield. Part of Waste and Pollution Management Programme.
Hydro-biological controls on transport and remediation of organic pollutants	Funded by EPSRC/NERC at the University of London. Part of Waste and Pollution Management Programme.
Predicting the potential for natural attenuation of organic pollutants in groundwater	Funded by EPSRC/NERC at the University of Sheffield. Part of Waste and Pollution Management Programme.
Integrated assessment and modelling of soil contaminant behaviour and impact at remediable urban sites	Funded by NERC at the University of Edinburgh. Part of Urban Regeneration and the Environment Programme.

Studies into metal speciation and bioavailability to assist risk assessment and remediation of brownfield sites in urban areas	Funded by NERC at the University of London. Part of Urban Regeneration and the Environment Programme.
In situ sensing of the effect of remediation on available metal fluxex in contaminated land	Funded by NERC at the University of Lancaster. Part of Urban Regeneration and the Environment Programme.
Bacterial biosensors to screen *in situ* bioavailability, toxicity and biodegradation potential of xenobiotic pollutants in soil	Funded by NERC at the University of Aberdeen. Three year project (10/96 until 10/99). Part of Environmental Diagnostics Programme.
Biodegradation of organic pollutants in the unsaturated zone of aquifers	Funded by NERC at the University of Sheffield. Eighteen month project (3/98 until 11/99). Part of Environmental Diagnostics Programme.
ENVIRONMENT AGENCY	
Cost-benefit analysis in remediation of contaminated land To provide advice on assessing the costs and benefits of different remedial techniques as part of a selection process	Completed project in LQ R&D for 1998/99.
Sustainability of remedial approaches for land contamination To provide guidance on assessing the wider environmental effect of different remedial strategies as part of a selection process	On-going project in LQ R&D for 1998/99.
Validation of remedial treatments To develop guidance for the verification of different remedial techniques to enable performance to be established during remediation and after works have been completed	On-going project in LQ R&D for 1998/99.
Guidance on the protection of housing on contaminated land To provide good practice advice in respect of remediation of land contamination and its return to beneficial use for the purposes of housing.	On-going project in LQ R&D for 1998/99.
Establishing woodland on contaminated land To consider the factors affecting the suitability of contaminated sites for establishment of woodland. To provide guidance on woodland establishment for the rehabilitation of land contamination.	Proposed new start for LQ R&D in 1999/00.
Field study of the performance of cover systems for land remediation To provide baseline field evidence for the long term performance of cover systems to improve regulatory confidence in their appropriate application.	Proposed new start for LQ R&D in 1999/00.
Validation of remedial performance: solidification and stabilisation To provide specific guidance on appropriate performance assessment criteria and verification protocols for solidification and stabilisation techniques in land remediation.	Proposed new start for LQ R&D in 1999/00.

Guidance on monitoring of long term performance of remedial treatments for land contamination To provide guidance on the monitoring requirements for land remediation	Proposed new start for LQ R&D in 1999/00.
SCOTLAND AND NORTHERN IRELAND FORUM FOR ENVIRONMENTAL RESEARCH	
Development of methods to establish remedial targets for the protection of human health and ecosystems.	On-going study; expected to be completed by Autumn 1999.
CONSTRUCTION INDUSTRY RESEARCH AND INFORMATION ASSOCIATION	
Contaminated land: in-house training material To produce training package aimed at the construction industry to raise awareness of the application of a range of remedial techniques.	On-going project.
Guidance on clean-up technologies for contaminated soil and groundwater: biological, physical and solidification / stabilisation treatments To provide good practice guidance on the selection and implementation of certain categories of process-based technologies.	On-going project.
Contaminated land: ecological management techniques To examine how the introduction and management of fauna and flora can be used in both remediation and ecotoxicological risk assessment of contaminated land.	Proposed new start 1999/00.
Aftercare management of redeveloped sites To provide guidance on the long-term monitoring and control of environmental contaminants.	Proposed new start 1999/00.

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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 February of 1999, over 385,000 confirmed releases had been reported, over 327,000 cleanups initiated, and over 211,000 cleanups completed.

Implementation of Hazardous Waste Cleanup Legislation

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 1998, EPA has authorized 33 states and territories to implement the 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. Some changes to the Superfund program have been implemented under EPA administrative reforms. As debate continues on changes to Superfund, there has been recent interest in amending the RCRA law. EPA and Congress agree the pace of RCRA cleanups should be increased and proposals are being considered to revise the law to exempt remediation wastes from certain hazardous waste management requirements, streamline the permitting process, and modify land disposal restrictions. In the meantime, EPA is launching an initiative to expedite cleanups through new guidance, rulemaking and public outreach. The Corrective Action program has set goals for the 1700 high priority facilities which include control of human exposure at 95 percent of sites, and control of ground water migration at 70 percent of facilities by the year 2005.

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.

Also, "Brownfields" initiatives have become prominent at federal and state levels. Brownfields are abandoned, idled, or under-used industrial and commercial facilities where expansion or redevelopment is complicated by real of perceived environmental contamination. Estimates range from 100,000 to 450,000 such sites in the Unites States. A growing realization in their great potential has heightened interest in their cleanup and redevelopment. EPA has funded 250 Brownfield Assessment Pilots and 16 Showcase Communities projects to stimulate work in this area. The Assessment Pilots are funded at up to $200,000 to local communities to chart their own course toward revitalization. The pilots are seen as catalysts for change in local communities, and often spur community involvement in local land use decision-making. A $1.5 billion Brownfields tax incentive has been enacted to further encourage cleanup and redevelopment.

2. IDENTIFICATION OF CONTAMINATED SITES

Almost half a million sites with potential contamination have been reported to state or federal authorities, based on a 1996 assessment. 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.

The most comprehensive information on technology use at waste sites is available for the Superfund program. Although they represent a small percentage of all contaminated sites, technology selection is representative of other hazardous waste sites. After reauthorization in 1986, most remedies involved some treatment of contaminated soil, as opposed to containment or off-site disposal. However, since 1993 there has been a steady decrease in the percentage of sites selecting some treatment. In 1996, the number of containment or off-site disposal projects exceeded the number of source control treatment remedies chosen for the first time since 1986. When treatment is selected, there is a trend toward greater use of in-situ processes. In 1996, in-situ technologies made up 66 percent of source control technologies in the Superfund program. Because there is no excavation, these technologies pose a reduced risk from exposure and can result in considerable cost savings, especially for large sites. Also, these processes have benefited from recent advances in site characterization technologies.

The most frequently selected treatment technologies for source control have been soil vapor extraction (SVE), solidification/stabilization and incineration. These technologies are followed by bioremediation and thermal desorption. Three-quarters of these remedial projects solely address organics, while the remainder address either metals alone or in combination with organics.

Ground water is contaminated at 70 percent of Superfund sites. Despite recent advances, 89 percent of remedies selected for controlling ground water plumes rely on conventional pump-and-treat technologies, 6 percent use in situ treatment in addition to pump-and-treat, and 5 percent utilize in situ technologies alone. The most frequently selected processes include air sparging, bioremediation, and dual-phase extraction. Many of the treatment technologies have only recently been selected and much work is underway to develop and test new processes. Figure 1 provides a qualitative illustration of pilot- and full-scale activity for some of the most prominent innovative plume management processes. Permeable reactive barriers are receiving a great deal of interest. Contrary to the conventional model for new technology development, there has been a rush to install full-scale reactive walls prior to completing pilot-scale testing. Early applications involved zero-valent iron to treat chlorinated solvents. Research and demonstration is focusing on materials to treat other contaminants such as chromium, polynuclear aromatic hydrocarbons (PAHs), and radionuclides. In addition, there are evaluations of installation methods and degradation rates for the treatment materials. For phytoremediation and bioremediation of chlorinated solvents, most activity is directed to pilot-scale testing. Natural attenuation has been used extensively to address petroleum contamination from underground storage tanks. This approach relies on microbiologic and abiotic processes. It is also being selected at hazardous waste sites, but primarily as a final polishing step as opposed to a sole remedy for a site.

Control of ground water plumes alone cannot always meet desired cleanup goals because of the presence of NAPLs. Figure 2 is another status diagram for the three most prominent dense non-aqueous phase liquid (DNAPL) technologies. Oxidation is frequently used by a limited number of vendors at full-scale, primarily for petroleum contamination. Otherwise, with a few notable exceptions, there is relatively little field demonstration activity for either surfactant and cosolvent flushing or thermal vaporization and mobilization processes. This is an important shortcoming due to the pervasiveness of the DNAPL problem.

<u>Trends and Anticipated Remedial Technology Use</u>

As part of the quest for more efficient and cost-effective site remediation technologies, a few subject areas are particularly worthy of note at this time. These represent some of the focus areas in greatest need of new technology.

The presence of DNAPLs (dense non-aqueous phase liquids) is probably the single most important factor affecting our ability to attain cleanup levels in ground water. Despite relatively few projects employing <u>DNAPL treatment</u> technologies, very important results were reported using steam extraction at a wood treating site in Visalia, California. Pumping and treating was removing about 10 pounds of creosote per week. Using in situ steam enhanced thermal treatment, approximately one million pounds of DNAPL was recovered in the first year of operation. These results are generating some optimism in terms of our ability to address prevalent DNAPL problems. This summer there will be a concurrent evaluation of three technologies to treat a TCE (trichloroethylene) DNAPL problem resulting from a spill at an old launch pad at Cape Canaveral, Florida. The project, led by the National Aeronautics and Space Administration with support from the Air Force, DOE and EPA, should provide comparative data for the three selected in situ processes: six-phase thermal heating, steam injection and oxidation

Another challenge is the difficulty of accurately <u>locating DNAPL</u> contamination in the subsurface environment. Current site characterization methods are often unable to locate the complete DNAPL mass which can lead to poorly informed remedy selections, inadequate remedial designs, and ineffective cleanups that must undergo costly re-evaluation and redesign. We need to answer the question "How can subsurface DNAPLs be reliably located through direct or indirect methods?"

There is a strong interest in bringing more efficiency to remediation efforts through use of <u>optimization</u> techniques. One way we can do this is by increasing the efficiency of long-term monitoring and remedial system performance for technologies such as pump and treat systems. Newly available software models have helped researchers demonstrate that costs and cleanup times can be significantly reduced by temporary activation and inactivation of pumping wells. This is an area capable of producing substantial savings.

As an alternative to pump and treat systems, monitored natural attenuation is receiving a lot of attention. Although natural attenuation offers significant advantages, there are some important uncertainties about attenuation rates and endpoints. EPA recently issued a final guideline on this process which emphasize the need for source control and rigorous long-term monitoring. Successful monitoring programs need to be demonstrated, perhaps using new sensor technology.

A significant new challenge is resulting from the emergence of a new contaminant, MTBE (the gasoline additive methyl tertiary butyl ether), which is being found with alarming frequency in ground water supplies around the country. This constituent is difficult to treat at the wellhead and in situ.

4. RESEARCH, DEVELOPMENT, AND DEMONSTRATION

Federal agencies currently are coordinating several technology development and commercialization programs. 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.

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 concluded 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.

Cooperative public-private initiatives are particularly important 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. Led by EPA, the Remediation Technologies Development Forum (RTDF) is a consortium of partners from industry, government, 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. EPA helps to develop partnerships between federal agencies (such as DOD and DOE) and private site owners (responsible parties, owners/operators) for the joint evaluation of 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. The program is organized around seven action teams which are co-chaired by a government and industry representative. Information is available from the RTDF home page at http://www.frtr.org.

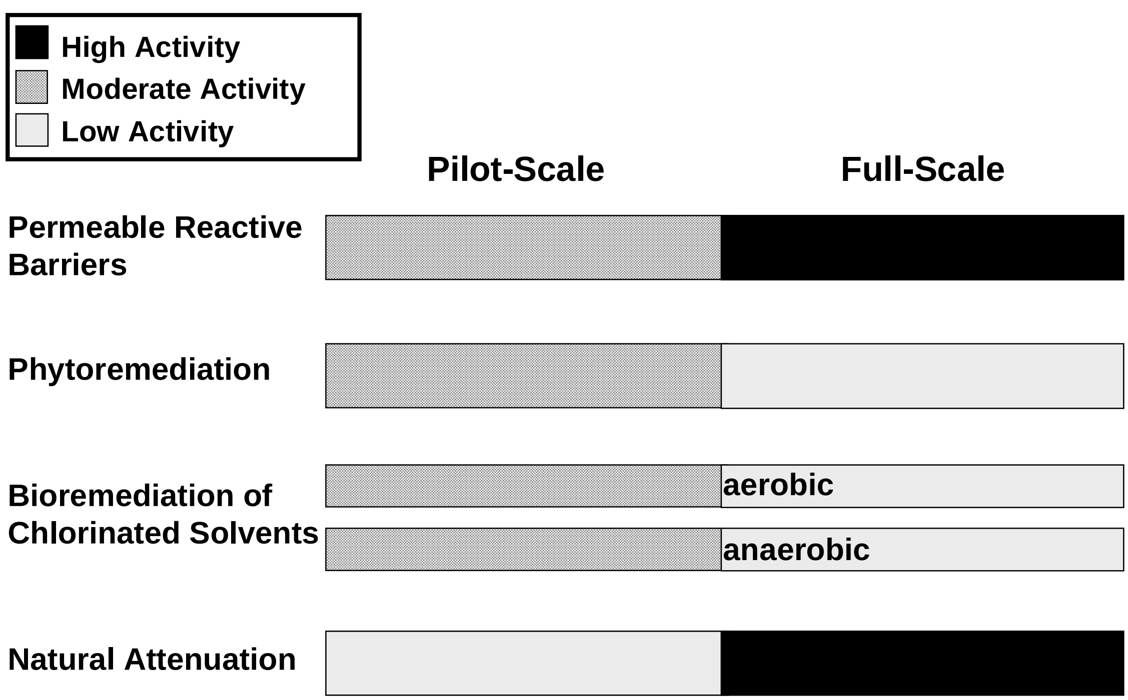
Agencies of the Federal Remediation Technologies Roundtable (including DOE, DOD and EPA) are involved in an ongoing effort to collect and distribute cleanup cost and performance data. The case studies aid the selection and use of more cost-effective remedies by documenting experience from actual field applications. Recently, the Roundtable announced publication of over 86 new studies of full-scale remediation and demonstration projects. This added to 54 studies which were published on two previous occasions. To better access this data, the Roundtable has improved it's web site (http://www.frtr.gov) to provide a convenient search capability. The Federal agencies coordinated their individual documentation efforts by using standardized procedures to capture their cleanup experience. These procedures are contained in an Interagency Guide which provides a recommended format for documenting cost, performance, and matrix and operational parameters for 29 specific technologies.

5. CONCLUSIONS

Legislative, regulatory and programmatic changes may alter the nature and sequence of cleanup work done at Superfund, DOD, and DOE sites. No major reauthorization of the Superfund program is anticipated and EPA will continue implementing administrative reforms and refining of improving them where necessary. EPA does, however, support new provisions that would provide targeted liability relief to qualified parties such as prospective purchasers, innocent landowners, contiguous property owners, and small municipal waste generators and transporters.

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.

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. Federal agencies are actively involved in developing and demonstrating new treatment and site characterization technologies. Various forms of partnering are instrumental in increasing the efficiency and effectiveness of these efforts.



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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