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Technology Programme for Soil and Groundwater Contamination 2000

Miljøstyrelsen
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Danish EPA Review

Technology Programme for Soil and Groundwater Contamination 2000

Contents

Summary

In 1996 a programme for development of remediation technologies relating to soil and groundwater contamination was set up.

The background and strategy of the development programme were described in the Danish EPA report "Programme for Development of Technology – Soil and Groundwater Contamination" of December 1996, and in each year since 1996 plans have been drawn up for projects in the following year.

Since the programme was launched, about 60 projects have been initiated, half of them to support testing of different remediation technologies. The other half supports development projects dealing with different remediation technologies, or enhances general knowledge on soil contamination.

This report gives an account of the progress of projects initiated, and presents proposals for projects in 2000 and 2001.

Focus is primarily on field projects relating to contamination from chlorinated solvents, hydrocarbons, including MTBE and PAHs. The report gives a survey of the technologies selected for testing.

Both public and private developers are eligible for support from the Danish EPA for projects documenting or testing specific remediation techniques. The Danish EPA also initiates development projects and other projects relating to soil pollution – primarily by tender.

At the turn of the year, the Danish EPA invites all regional authorities to submit proposals for sites which can be used to document specific remediation technologies highlighted in the programme.

1 Background

The Waste Deposits/Landfills Act /1/ stipulated a special programme for developing remediation technologies within the field of soil contamination. The Contaminated Soil Act of 2 June 1999 /2/ states that the Minister for Environment and Energy is responsible for development and testing of new technology within soil contamination. The funds allocated for the programme are determined in the annual national budget.

The background and strategies for the development programme are described in "Program for Teknologiudvikling, jord- og grundvandsforurening, december 1996" [Programme for Development of Technology, Soil and Groundwater Contamination" /3/. The "Udbygning af Program for Teknologiudvikling, jord- og grundvandsforurening for 1998 og 1999" [Extension of Programme for Development of Technology, Soil and Groundwater Contamination /4/ contains descriptions of areas of special interest and project proposals for 1998-99.

This programme features a description of the revised overall objective of the programme (section 2), the status of the programme (section 3), and section 4 lists areas of contamination against which the Technology Programme should be directed during the next few years. Section 5 features descriptions of project proposals for field projects and desk studies planned for the year 2000.

The National Budget for 2000 assigns an amount of DKK 15 million for technology development. The National Budget contains the following:

"The purpose of establishing this programme is, through coordinated efforts within the area of technology, etc., to render remediation of deposits/landfills more efficient and cost-effective and to remove barriers for development and use of target-specific technologies directed towards contamination of soil and groundwater. The funds assigned may e.g. be used to pay for gathering experience and knowledge on soil contamination, as well as development and testing of new technologies. Funds may also be used to develop and test methods, e.g. with a view to determining criteria, risk assessment, and employment analyses, as well as for documenting, assessing and comparing the effectiveness, efficiency, cost, and environmental impact of remediation techniques. The funds allocated may moreover be used to co-finance development and testing of remediation projects prepared and funded by county councils and the local authorities of Copenhagen and Frederiksberg, provided that such projects involve some aspect of development. Moreover, costs may be defrayed and support granted for insurance concerning any liability in connection with remediation work. Costs may be defrayed and support granted for information, advertising and tenders with respect to projects as well as for audits, evaluations, and communication of results, etc".

2 Contents of the programme

One of the objectives of the Contaminated Soil Act /2/ is to create a basis for developing and using new remediation technologies for contaminated soil and groundwater.

The overall objective of the Technology Programme is to create a basis for carrying out more efficient (in terms of both environmental impact and cost) remediation of contaminated sites, including testing and implementation of new and recent remediation technologies, both high-tech and low-tech.

- The Technology Programme funds are to be used for development and documentation of technologies which can be used under Danish conditions and for typical contaminants.
- The Technology Programme funds are to be used for projects which test the limits of what is technically possible within fields such as remediation levels, treatment and processing technologies, cost reduction, and documentation.
- The Technology Programme funds are to ensure that the results of the completed projects are made available to all interested parties, in particular to those authorities which are to assess the remediation projects.

The programme has been in force since December 1996. The present programme indicates a series of areas which should be addressed in terms of technology development during the next 2-4 years. This is to ensure that the funds available are not spent *ad hoc* on individual projects, but are aimed specifically at particular areas or issues.

2.1 Objective

The overall objective for the Technology Programme is to identify remediation technologies, so that in the future, it will be easier to select the optimum remediation technologies for each site in terms of cost, environmental benefits, and technical issues.

The objective is that approximately 70 per cent of funds should be spent on testing various technologies, and the remaining 30 per cent should be used for desk studies which can help promote remediation efforts or provide a better basis for understanding contamination spreading and risk assessment.

The objectives for testing various remediation technologies are as follows:

- To test, assess, and describe the most promising technologies.
- To test technologies directed at those substances which present the greatest problems in terms of the environment and health.
- To test technologies within those areas where large sums of money are used for remediation.
- To initiate approximately 10 - 20 field projects per year.
- To aim projects at practical use.
- To conduct all tests with specific aims and at a high professional level.
- To ensure all tests are validated by impartial parties.
- To extract knowledge about the advantages and limitations of the technologies during testing.
- To prepare technical reports for the technologies tested.
- To publish project reports regularly on the Internet and in the journal *Ny Viden* ['New Knowledge'].
- To present the results at meetings.
- To give counties the opportunity, once a year, to submit suggestions for sites for testing of technologies.
- To provide counties with an opportunity to make suggestions on a continuous basis for technologies to be tested.

- To provide county employees with opportunities to become professionally involved in the projects.
- To prepare a catalogue of all the technologies tested after five years from the launch date of the programme.
- To ensure coordination with other schemes and programmes.
- To carry out an assessment and evaluation of the programme five years after the launch date.

It is expected that an overview of the possible remediation technologies and predicted remediation levels will be available after five years from the launch date of the programme. On this basis, it will be possible to identify areas where there is a need to develop and test other technologies at laboratory level. An overview of the amount of remediated soil which cannot be freely used, but must be deposited after remediation is also expected to be available.

The objectives of the desk studies are:
- To identify remediation technologies for testing.
- To identify potential remediation technologies for various types of contamination.
- To improve the basis for risk assessment of contamination of soil and groundwater.
- To improve the available knowledge about the risks associated with various contaminants.

It is expected that an overview will be available within five years after the launch date of the programme, outlining the potential remediation technologies which exist to combat those contaminants which present the greatest problems in terms of the environment and health.

2.2 Development and use of technology

Development of specific technologies is usually carried out in stages as follows:
1. Testing in laboratories.
2. Pilot-scale testing.
3. Full-scale demonstration under natural conditions.
4. Commercial use.

Significant research efforts usually precede stage 1, laboratory testing. During the first 3+ years after the launch of the Technology Programme, the technology projects initiated have primarily fallen within stages 2 or 3.

Danish as well as foreign experience shows that considerable barriers may exist between stages 1 and 2 and again between stages 2 and 3. These barriers include optimising method use, concept development, geological heterogeneity, and sufficient remediation in relation to applicable soil-quality criteria.

The objective for the Technology Programme for 2000-2001 is primarily to help overcome these barriers for technologies which are deemed suitable for use under Danish conditions and which have typically completed the first stage. However, it is expected that some laboratory testing (stage 1) will be initiated during this period.

2.3 Transfer of technology

Development and testing of innovative remediation techniques have predominantly been carried out in the USA, and primarily by private enterprises. The American Environmental Protection Agency (US-EPA) supports the development and demonstration of innovative remediation techniques through initiatives such as the SITE Programme (Superfund Innovative Technology Evaluation Programme). Moreover, various support schemes exist in the US, both under the auspices of the Department of Energy (DOE) and the Department of Defence (DOD). In Europe, Dutch and German enterprises lead the development and use of innovative remediation techniques.

The Danish technology-development projects carried out during the last three years have mainly been conducted through technology transfer from the USA.

As yet, no special requirements have been made of enterprises in Denmark or abroad to document the effectiveness of the remediation methods used. The US-EPA is considering possible ways of setting out such requirements with a view to achieving environmentally acceptable remediation.

The Danish EPA takes the view that the Technology Programme must continue to ensure purpose-directed transfers of technology, testing, and implementation in order to adapt results from e.g. the USA, the Netherlands, and Germany to Danish conditions.

2.4 Other issues

The Technology Programme also comprises other areas insofar as these areas can contribute to promoting remediation measures or if they can bring about a better basis for understanding the spread of contamination and for risk assessment.

The programme still cannot comprise development of technology for remediation of surface contamination from e.g. nitrate and pesticides.

2.5 Limitations of remediation methods

The Programme for Technology Development from 1996 /3/ contained the following description of the situation within soil remediation:

- The methods which are used on a routine basis are mainly off-site methods (remediation carried out elsewhere), whereas only a minority of the methods are in-situ (on-site remediation) methods.
- There are many methods for remediation of organic contamination. The opportunities for cleaning up inorganic contamination are more limited.
- The known techniques can to some extent be used for remediation of sandy soil types, while only a minority of the methods can be used for remediation of loamy/clay soil types and mixtures, e.g. mixtures of soil and rocks or waste.
- In-situ techniques are more difficult if the soil is inhomogeneous.
- Some of the most common soil-remediation techniques change the original soil structure.
- Many in-situ techniques have long operating times before acceptable end levels can be attained, or if the amount of unserviceable residual products is to be minimised.
- Documentation for the effectiveness of in-situ techniques is often sparse.

Therefore, for almost all in-situ and on-site techniques there is a need for controlled pilot-scale testing which aims at concept development and method optimisation, as well as a need for establishing how effectively these methods can be used to address the problems in real life. However, with regard to the biological methods, the primary need is to optimise the methods. With regard to on-site methods, such as on-site thermic treatment and other remediation methods, which all require relatively large-scale investments, the development potential is less attractive if such methods are directed solely at a relatively small domestic market.

This description still largely applies to the situation within this field. During the last three years, one of the changes is that it has become more 'common' to carry out in-situ remediation. Moreover, there is more awareness of issues such as dimensioning plants, the limitations of the methods, and especially operating conditions. These changes are partly due to the Technology Programme. It is still estimated that there remain few opportunities for remediating inorganic contamination, and that remediation of contaminated inhomogeneous clay soil presents a significant problem.

3 Status for the programme

3.1 Introduction

During the past three years, the Technology Programme has primarily concentrated on remediation technologies for chlorinated solvents and oil and petrol contamination. The programme has brought us forward to several new technologies directed towards chlorinated solvents, including thermically assisted remediation and reactive permeable barriers. The programme has also yielded a low-cost method for remediation of groundwater which has been contaminated by chromium(VI).

A more detailed assessment of air sparging, modified stripping, geo-oxidation and fracturing will be available shortly. All of these methods are in the process of being tested which will be concluded within the next year.

A series of phytoremediation projects have been initiated. At present, the conclusion is that it is not possible to remediate inorganic combined contamination by means of plants. A number of phytoremediation projects to combat oil and PAH contamination have been established. The results of these will not be available until three to four years from now.

A product has been tested which was expected to be able to accelerate degradation of oil contamination. Tests demonstrated that the product had no discernible effect.

During the activity period so far, a good overview has emerged of potential remediation techniques to combat e.g. heavy-metal contamination and MTBE contamination of groundwater. Specific techniques such as vacuum-vapour extraction, thermically assisted remediation and natural attenuation have been subjected to more detailed description and assessment.

Despite several attempts, suitable methods for combined contamination have not yet been found.

3.2 Overview of field projects initiated

Below is a short outline of the methods utilised in field projects initiated in the various areas of special interest. Appendix A features a list of all projects (field projects and desk studies) initiated during the entire period (from 1996 to 1999).

Method:	**Area of special interest:**
• Air sparging	Chlorinated solvents, oil/petrol
• Soil-vapour extraction	Chlorinated solvents
• Modified stripping method	Chlorinated solvents
• Reactive permeable barrier	Chlorinated solvents and chromium(VI)
• Vapour stripping	Chlorinated solvents
• Natural attenuation of chlorinated solvents	Chlorinated solvents
• Natural attenuation of oil/petrol components	Petrol
• Geo-oxidation	Petrol
• Degradation accelerator for oil degradation	Oil
• ORC (Oxygen Release Compound)	Petrol

• Phyto remediation	Oil, PAH and heavy metal
• Elektrodialytic remediation	Chromium, copper and arsene
• Reduction of contamination from chromium(VI) to chromium(III),	Chromium
• Fracturing	Chlorinated solvents
• Passive vapour extraction	Chlorinated solvents
• Soil leaching	Inorganic contamination and combined contamination
• Accelerated/forced leaching	Tar components.

The results of these tests will be published on a regular basis within the next few years.

3.3 Funding

Since 1996, the annual funds allocated within the national budget have amounted to:
1996: DKK 10.0 million
1997: DKK 15.0 million
1998: DKK 19.4 million
1999: DKK 16.0 million

4 Areas of special interest

The "Programme for Technology Development and Contamination of Soil and Groundwater, December 1996" /3/ features descriptions of the contamination areas against which the Technology Programme should be directed during the next five years. These areas were identified on the basis of information from the ROKA Database 1995, where e.g. the frequency of the various contamination types in soil and groundwater were compared. This identified the following contamination areas (areas of special interest) to be addressed by the programme during the next two to five years:

- Soil and/or groundwater which has been contaminated by chlorinated solvents.
- Soil contaminated by heavy metals.
- Oil/petrol contamination of soil and groundwater (including MTBE).
- Tar/PAH contamination of soil (including NSO compounds).
- Combined contamination.
- Landfills with leaks of landfill gas.

During the next few years, measures must continue to ensure testing and documentation of methods for remediation of contamination which threatens the groundwater (chlorinated solvents and oil/petrol contamination, including MTBE contamination). Moreover, plans have been made to test methods against tar/PAH contamination. There are still plans to test various in-situ technologies. In addition to this, plans have been made to extend tests of various existing or new soil-remediation plants, e.g. with regard to combined contamination and heavy-metal contamination which both present a significant soil-contamination problem. Future projects will focus on the quality of the end product which appears after remediation, with especial focus on assessing whether the remediated soil can be used freely.

In special situations, it may be relevant to test methods for remediation of hotspots with pesticide contamination.

For future projects, an important area of special interest will be environmental assessment and financial assessment of individual techniques and of remediation as such. In addition to this, an important area of special interest will be the efforts to minimise operating costs for the various remedial measures. During the following years, techniques will also be tested within the other areas of special interest.

5 Project proposals for 2000-2001

The overall objective of the Technology Programme is to create a basis for more efficient (in terms of both environmental impact and cost) remediation of contaminated sites, and to test new and recent remediation technologies.

Figure 1 shows an outline of a traditional sequence of events for a remedial project. The scope of the work initiated under the auspices of the Technology Programme depends on the stage which surveys and remedial measures have reached for each specific site.

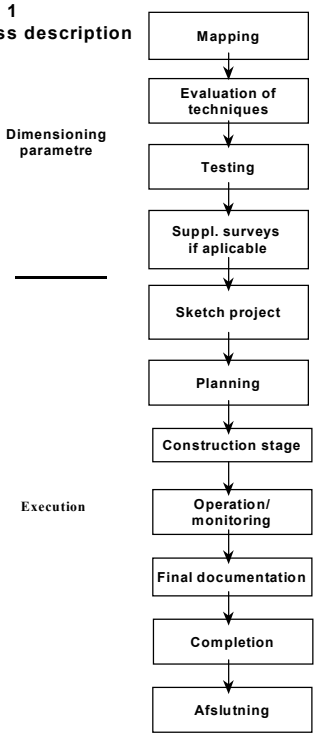
5.1 Objectives of field projects

The objective of the field projects is to test and provide documentation for methods, and in particular to assess whether the preconditions set out are being met. When testing these methods, specific requirements must be stipulated for preliminary surveys and preliminary tests to dimension and design plant. On the basis of tests, prognoses are prepared for remediation work, especially with regard to duration and remediation levels. Before the remedial measures are initiated, a process of regular operation control and final documentation of the remediation must be described in detail. In addition to this, environmental assessments and financial assessments of the costs and benefits involved in individual techniques are carried out. Appendix C features a paradigm for a list of contents and Appendix D features a budget for a technology project.

The results of the field projects, along with studies of the literature available, are issued as general documents (reports, guidelines, etc.) on the use of the methods under Danish conditions.

The results of the Technology Programme are continuously presented and communicated by preparing publications which will also appear on the Danish EPA homepage. Moreover, the programme and projects will be presented on a regular basis at various meetings such as ATV meetings (ATV - the Danish Academy of Technical Sciences) and meetings at the Information Center on Contaminated Sites, IDA - the Society of Danish Engineers and universities.

Figure 1
Process description



5.2 Technologies to be tested

Below is a list of the technologies to be tested within the next five years. This list is subject to adjustment in the event of more detailed surveys (Danish or foreign) showing that testing of a specific method would not be relevant.

Technique	Chlorinated solvents	Oil/ Petrol	MTBE	Tar/ PAHs	Other
Techniques based on stripping (all at development stage 3):					
Thermically assisted remediation	X	X			
Modified stripping methods (in well)	X	X	X		
Dual-phase extraction	X				
Bio-vapour extraction	X	X	X		
Fracturing	X	X			
Degradation under natural conditions (at development stage 2 or 3):					
Degradation	X	X		X	
Biological and chemical remediation methods (at development stages 1, 2, or 3):					
On site biological remediation of groundwater	X	X			
Biological remediation of contaminated soil	X	X			
Degradation of MTBE contamination by means of bacteria			X		
Remediation by addition of oxygen		X	X		
Chemical remediation by addition of hydrogen	X				
Remediation with ozone		X			
Remediation of groundwater (at development stage 2 or 3):					
Fluid bed remediation of contaminated groundwater	X				X
Flotation techniques	X	X			X
Optimising remedial pumping	X	X	X	X	X
Other methods:					
Method for eliminating free phase	X	X			
Soil-remediation plant	X	X		X	X

Other field projects:

- Testing of alternative examination methods, e.g. field analyses, boring methods, and equipment for sample extraction.
- Assessment of examination methods for mapping.

5.3 Field projects with high priority for 2000 - 2001

Within each area of special interest, the projects for 2000-2001 have been listed in the following. The number of projects which can be initiated depends on the scope of the individual projects and the cost. Mapped sites are preferred for testing of the technologies.

5.3.1 Chlorinated solvents

- **Thermically assisted remediation (development stage 3)**

Thermically assisted remediation involves heating the soil, which causes the volatile contaminants to be more effectively and efficiently eliminated. In the USA, experiments have been carried out on heating the soil by means of five different methods:
- injection of hot air and steam,
- injection of hot water,
- electric heating by means of electrodes and low-frequency electricity,
- heating by means of radio waves and microwaves via aerials, and
- direct thermic conduction into soil by means of a heating blanket or a heating well.

The assessment is that it is relevant carry out further testing of the methods directed against contamination in clay strata and beneath the groundwater level. Plans have been made to initiate one or two additional field projects on selected methods.

- **Dual-phase extraction (development stage 3)**

Dual-phase extraction is a remediation method which is used in less permeable strata, where more usual methods such as soil-vapour extraction and/or air sparging cannot be used. Dual-phase extraction involves establishing a powerful vacuum in the remedial boring, so that both pore air and pore water/groundwater is extracted simultaneously from the contaminated volume of soil. The extracted air/water is stripped and remediated in a plant. A field project is expected to be initiated.

- **Modified stripping methods, e.g. well-vapour extraction (development stage 3)**

These modified methods involve combining the recirculation of groundwater with stripping and thus combining air sparging with soil-vapour extraction in the same borings (e.g. in-well stripping or bioslurping). In the USA, various types of modified methods exist. One or two field projects using these methods against chlorinated solvents are planned.

- **Fracturing (development stage 2 or 3)**

One or two projects are expected to be initiated on the basis of a desk study describing various fracturing methods. Fracturing involves creating artificial fissuring of low-permeable strata, e.g. by injecting a fluid or air into the bottom of a boring at high pressure.

- **Chemical remediation by addition of hydrogen (development stage 3)**

It is to be assessed whether it would be relevant to initiate a project on chemical remediation by addition of hydrogen**.** The method involves accelerating the degradation of chlorinated solvents by establishing anaerobic conditions. This changes the redox conditions, so that the potential for degradation of PCE and TCE is increased. It may be relevant to assess whether this method is effective against deep contamination of chlorinated solvents.

- **Optimising remedial pumping (development stage 3)**

Efforts are to made to either optimise operation of remedial pumping at a site, or to test alternative remediation methods.

- **Phyto remediation (development stage 1 or 2)**

A phyto-remediation project for soil and groundwater contaminated by chlorinated solvents may be carried out.

5.3.2 Oil/petrol

- **Modified stripping methods, e.g. well-vapour extraction (development stage 3)**

These modified methods involve combining the recirculation of groundwater with stripping and thus combining air sparging with soil-vapour extraction in the same borings (e.g. in-well stripping or bioslurping). In the USA, various types of modified methods exist. One or two field projects using these methods against contamination from oil or petrol are planned.

- **Accelerated/forced degradation (development stage 3 or 4)**

Tests carried out in the USA show that degradation of oil-/petrol contamination can be accelerated/forced by addition of oxygen, e.g. as ORC. One or two field projects using these methods against contamination of oil or petrol contamination and possibly MTBE contamination are planned.

- **Biological filters (development stage 2 or 3)**

Testing is to carried out on various biofilters for remediation of air and water contaminated by oil or petrol. These tests are to be compared to carbon remediation.

5.3.3 MTBE

- **Modified stripping methods, e.g. well-vapour extraction (development stage 2 or 3)**

These modified methods involve combining the recirculation of groundwater with stripping and thus combining air sparging with soil-vapour extraction in the same borings (e.g. in-well stripping or bioslurping). In the USA, various types of modified methods exist. A field project using these methods against contamination from petrol or MTBE is planned.

- **Degradation of MTBE by means of bacteria (development stage 1, 2 or 3)**

In the USA, a culture of bacteria capable of degrading groundwater contaminated by MTBE has been isolated. Preliminary Danish tests show that there is a potential for using this culture of bacteria in an on-site remediation filter. Plans have been made for carrying out one or two field projects where this method is compared with other remediation methods.

- **Remediation of MTBE by means of filtering (development stage 1, 2 or 3)**

The desk study "Remediation techniques for groundwater contaminated by MTBE" recommends testing of various filter types for on site remediation of contaminated groundwater. One or two field projects are to test and assess various filters (carbon filters, addition of ozone combined with biological filtering, etc.).

- **Biological remediation of MTBE (development stage 2 or 3)**

The latest results from USA show good effects from passive remediation of groundwater contaminated by MTBE by letting the contaminated water pass through an oxygen barrier in the groundwater aquifer. One or two field projects have been planned.

5.3.4 PAH/tar contamination and combined contamination

- **Soil contaminated by tar used in noise-deflecting barriers, etc. (development stage 3)**

One or more field projects are to provide documentation for the risk of spreading contamination when soil contaminated by tar is used to build noise-deflecting barriers and roads.

- **Remediation of combined contamination, i.e. in a thermic processing plant**

Plans have been made to document how combined contamination is remediated, e.g. in thermic processing plants and other existing soil-remediation plants. Special focus will be placed on the issue of the levels of remediation which can be achieved and on the end products.

- **Natural attenuation of PAHs in water (development stage 3)**

A field project is to survey and document the natural attenuation processes for PAHs. This includes formation of attenuation products.

5.3.5 Gas from landfills

- **Risk of gas from landfills**

Depending on the result of an ongoing desk study which carries out risk assessment of explosion hazards from gas in landfills, it may be relevant to carry out a field project for further elucidation and clarification.

5.4 Desk studies for 2000-2001

The following desk studies are planned.

5.4.1 Computer models

Computer models are to be set up and tested for various stripping methods. An English version of the Danish EPA software "JAGG" is to be prepared.

5.4.2 Assessment of alternative on-site methods for remediation of air and water

Various methods are to be described and assessed in order to reduce operating costs for remediation of contaminated air and groundwater. One or two field projects are expected to be initiated on the basis of the results of this project.

5.4.3 Financial assessments of remediation of contaminated soil and groundwater

A paradigm for calculating the financial costs involved in establishing a remediation project is to be prepared. Key figures are to be calculated for individual techniques on the basis of specific projects. The financial costs for the various techniques are to be compared.

5.4.4 Assessment of the amount of soil remediated at plants

Examinations are to be carried out of how much soil is sent to be remediated and how big a proportion of this soil is remediated so that it can be used freely and how much soil is subsequently deposited. This survey is to extend to various contaminants.

5.4.5 Assessment of contamination effects on indoor climates

Coherent and interconnected data is to be collected for recording volatile contaminants underneath floors and in buildings with a view to carrying out an assessment of how floor constructions reduce contamination concentrations.

5.4.6 Determination of concentrations at source in mobile pore water in the unsaturated zone

This project is to result in guidelines on how concentrations at source can be determined, thus making risk assessment more accurate.

5.4.7 Determining the horizontal longitudinal dispersivity in lime aquifers which are representative for Danish conditions

5.4.8 Preparation of hydrogeological mapping requirements with a view to determining the degradation rate locally.

5.4.9 New methods for characterising contaminated sites

There is a need for methods and techniques which can characterise and describe contamination in a better and more cost-effective way. This will be carried out when there is a sufficient number of methods/techniques which can be described and possibly field tested.

5.5 Other projects for 2000 - 2001

The following other projects are planned for the soil-contamination area.

- Standardisation work 'ISO' under the auspices of the EU.
- Assessment of mercury contamination of soil in Denmark.
- Evaluation of remediation carried out under the Danish Petroleum Industry Association for Remediation of Retail Sites Programme.
- Method testing of a PAH analysis method.
- Standardisation of method for determining total carbon-hydrogen contents, including BTEX contents, in water.
- Assessment of PAH ¤METABOLITTER. A survey may be carried out of whether PAH ¤METABOLLITER, which appear in connection with degradation of PAHs, present a problem in terms of the environment and human health.
- Data model for contaminated soil. A data model (a logical description which operates independently of specific systems) for data on soil contamination is to be prepared.
- Continuation of projects on absorption of contaminant compounds in fruit and vegetables.
- Health-based criteria for soil and groundwater.
- Survey on bioavailability for contaminants in soil.
- Systematisation of data on diffuse contamination, phase 2.
- Evaluation of the Technology Programme.
- Information. Preparation of a leaflet.

6 Types of projects initiated

Both public and private developers can apply for public support for documentation or testing of specific remediation technologies. The Danish EPA initiates desk studies and other projects on soil contamination itself - primarily by inviting tenders.

Around the turn of the year, the Danish EPA will call on all counties to provide suggestions for sites which can be used to document selected remediation technologies in accordance with the programme. If counties are planning to use recent remediation technologies other than those specified in the programme, they counties are encouraged to submit these suggestions and proposals to the Danish EPA on a regular basis. Occasionally, the counties are called upon to submit proposals every six months. Private developers can submit proposals for projects on a regular basis. This is usually done through the counties.

On the basis of an expert technical survey of the proposals submitted from both counties and private developers, a number of sites are selected for closer inspection. Subsequently, priority is assigned to projects where a technology project can be attached. The actual selection process is carried out in collaboration between the expert secretaries (see Section 7) and the Danish EPA.

A decisive factor in the selection of sites is whether knowledge and experience of general relevance can be obtained from the project. For this reason, the sites selected are primarily representative of Danish geological conditions and of the types of contamination mentioned in the programme.

When a site has been selected, the developer (usually the developer's advisor) and the expert secretary cooperate on preparing a project description for the technology project. This description forms the basis for the support agreement.

With each case, a specific agreement is entered into between the developer (the county or others) and the Danish EPA regarding allocation of costs. The point of departure is:

- That Technology Programme funds pay all the additional costs occasioned by a technology project being associated with the remediation project; i.e. all additional surveys, elucidation, interpretations, etc.
- In those situations where there is a greater degree of uncertainty regarding the relevance and usefulness of the methods and this gives rise to a risk for subsequent additional measures in the form of traditional remedial measures, greater support is granted on the basis of a specific assessment. Technology Programme funding will not be used for any subsequent additional traditional remedial measures.

The developer (county or private developer) receiving support assumes the function of developer for the total project. Appendix B shows a paradigm for an example of support. This paradigm is adjusted on a regular basis.

7 Organisation

The organisation behind the Technology Programme is described in the following - including a description of the various parties involved in the work. Figure 2 features an organisational chart. Expert secretaries are only appointed for field projects.

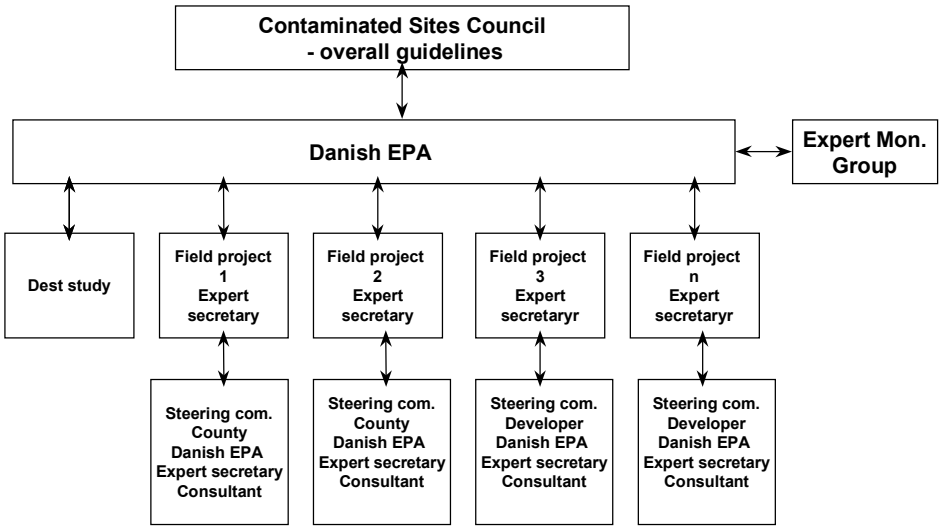
7.1 The Danish Contaminated Sites Council

In accordance with the amendment of the Waste Deposit/Landfills Act /1/ a Danish Contaminated Sites Council has been set up with the purpose of, e.g., providing counsel for the Minister on general issues on technology development. The explanatory memorandum accompanying this legislative proposal states that "An amount shall be appropriated annually from the landfill funds for promoting technology development. Administration of these funds shall be carried out by the Danish EPA, which shall present proposals for principles and programme areas for the Danish Contaminated Sites Council." "The Council shall prepare an annual report for the Minister for Environment and Energy. The Council shall also carry out assessment of more general needs for technology development and shall each year present their recommendations with regard to principles and programme areas, including the distribution of funds within these areas."

In accordance with Section 8 b of the Waste Deposit/Landfill Act, the Minister for Environment and Energy set up the Danish Contaminated Sites Council in the autumn of 1996. The Danish Contaminated Sites Council comprises the following members:

- The Danish EPA. Presidency.
- The Association of County Councils in Denmark. 2 persons.
- Municipality of Frederiksberg.
- Municipality of Copenhagen, Environmental Protection Agency, Copenhagen.
- The National Association of Local Authorities in Denmark.
- The Confederation of Danish Industries.
- The Danish Society for the Conservation of Nature.
- The Danish Water Supply Association and The Joint Organisation of Private Waterworks in Denmark in joint membership.
- The Danish Family Farmers' Association, The Danish Farmers' Union, and the Danish Agricultural Council.

Figure 2
Organisation of technology development



7.2 Expert Monitoring Group

An expert-monitoring group has been set up to provide expert advice to the Soil Contamination Division of the Danish EPA. This expert-monitoring group is to:

- Provide advice to the Danish EPA on general technical issues.
- Ensure coordination with initiatives within other areas.
- Advise the Danish EPA on the selection of players.

The expert-monitoring group comprises experts from:

- The Information Center on Contaminated Sites.
- The National Environmental Research Institute.
- GEUS - The Geological Survey of Denmark and Greenland.
- The Danish National Railways Agency.
- The Danish Defence Construction Service.
- The Danish Petroleum Industry Association for Remediation of Retail Sites.
- The National Forest and Nature Agency.
- The Danish EPA.

The objective is to disseminate information to other public authorities working with remediation of contaminated sites.

7.3 Expert secretary

For most field projects, the Danish EPA will appoint an external expert secretary. These secretaries assist the Danish EPA on field projects and help to ensure that these projects are carried out at high levels of professionalism and in accordance with the guidelines stipulated. The expert secretaries are appointed on the basis of their technical expertise within the relevant area. Appendix A features a list of the expert secretaries.

Below is a description of the main tasks of the expert secretaries:

- To ensure a high level of professionalism in the description of the projects.

- To cooperate with the Danish EPA on defining frameworks and objectives for the projects, so that these projects can form the basis for preparing guidelines and standards.
- To supervise and check up on the projects during their execution and to ensure that projects are documented.
- To use literature to remain up-to-date on the method selected, both domestically and internationally.
- To participate in coordination of the various field projects. This includes participation in meetings with the Danish EPA and other expert secretaries.
- Possibly to be involved in phrasing the general statements (reports, guidelines, etc.) which are to be the outcome of the project.

7.4 Steering committee for the field projects

A steering committee is set up for each field project and most desk studies. For the field projects, this committee comprises a representative for the county in which the field project is carried out (the president), the president's consultant, the external expert secretary, and the Danish EPA. The objective of the steering committee is to ensure regular dissemination of information and discussion on the progress of the project. The county authorities, who are also the developer, are in charge of contact to the consultant, contractors, residents, etc. For the desk study, the steering committee consists primarily of persons with a technical interest and expertise within the relevant field, public officials, and the Danish EPA.

8 References

1. Amendment to the Waste Deposits/Landfills Act.

2. Act No. 370, ”Contaminated Soil Act” of 2 June 1999.

3. Programme for Technology Development, Soil, and Groundwater Contamination, December 1996.

4. Extension of the Programme for Technology Development, Soil, and Groundwater Contamination for 1998 and 1999.

Appendix A

At the end of 1996, the Technology Development Pool was established as part of the organisational changes carried out within the deposit/landfill area. In December 1996, the Danish EPA prepared a programme for this programme, which is described in more detail in *Depotredegørelsen om affaldsdepotområdet 1996 (Redegørelse fra Miljøstyrelsen nr. 2 1997)*. [The Waste Deposit Report 1996 (Danish EPA Report No. 2, 1997)]. The Waste Deposit Report 1997 features a description of the extension of the programme with areas of special interest and project proposals for 1998 and 1999 (Redegørelse fra Miljørstyrelsen nr. 1 1998) [The Danish EPA Report No. 1, 1998].

This section provides a status report on the activities initiated since the launch of this programme in December 1996.

1. Status for field projects

The objective of the field projects is to test and create documentation for the methods under Danish conditions and in particular to assess whether the targets are being achieved. When testing these methods, specific requirements are stipulated with regard to preliminary surveys and preliminary tests to dimension and design plants. On the basis of tests, prognoses are prepared for remediation work, especially regarding duration and required remediation. Before the remedial measures are initiated, a detailed description must be made of a process of regular operation control and final documentation of the remediation. It is expected that better documentation, etc., will result in new ideas on how to develop and optimise methods.

1.1 Status for field projects initiated in 1999

- *Passive vapour extraction*. Allerød, County of Frederiksborg.

Support has been granted for documentation of passive vapour extraction at a site with an unsaturated zone consisting of sedimentary sand deposits with a thickness of approximately five metres, situated underneath a layer of moraine clay with a thickness of ten metres. Passive vacuum-vapour extraction is a technique which utilises the natural pressure gradients between the atmosphere and the unsaturated zone to force the pore air up to terrain level. In the USA, special boring caps called 'BaronBall' have been developed, which allows the pore air to escape from borings exclusively. This project will examine how these gradients can be used for preventing/remediating contamination of groundwater resources. The method is deemed to be particularly useful in cases where active vapour-extraction methods are no longer effective. The passive vacuum-vapour extraction has been established.

- *Passive vapour extraction.* Askov, County of Ribe.

Support has been granted for testing passive vapour extraction at a site with an unsaturated zone consisting of sedimentary sand deposits with a thickness of approximately 20 metres, situated underneath a layer of moraine clay with a thickness of ten metres. Monitoring will be initiated in the beginning of the year 2000.

- *Passive vapour extraction.* Fakse, County of Storstrøm.

Support has been granted to test passive vapour extraction at a site with a layer of fissured lime with a thickness of approximately 25 metres, situated underneath a covering layer of moraine clay with a thickness of 12 metres, in which approximately two to four metres of dry gravel is embedded. As a supplement to passive vapour extraction, tests are also being carried out of a vacuum-vapour extraction system based on renewable energy sources (from the sun and wind).

- *Phyto remediation* The Danish Petroleum Industry Association for Remediation of Retail Sites, Rønnede, County of Storstrøm.

Support has been granted for testing phytoremediation of contamination from oil and petrol. The site has been selected because the contamination is clearly demarcated and because of the opportunities for examining the effect of this method on groundwater. A mixture of willow and poplar was planted at the site in spring 1999.

- *Phytoremediation.* Allerød, County of Frederiksborg.

Support has been granted to test phytoremediation of oil and tar contamination. The site has been selected due to the heterogeneous contamination and because of the opportunities for testing the effect of this method on groundwater. The site has been registered as a landfill. There is extensive oil contamination and less extensive, but heavy, tar contamination. A mixture of willow and poplar was planted at the site in spring 1999; the trees planted within the tar-contaminated areas were inoculated with common bacteria.

- *Phytoremediation.* Valbyparken, Municipality of Copenhagen.

Support has been granted to test phytoremediation at a site which was previously a landfill which was also used for sludge deposits. The site was selected because it has been contaminated by various oil types and PAH and because of the opportunities for testing the effect of this method on groundwater. A mixture of willow and poplar was planted at the site in spring 1999; some of the trees planted were inoculated with natural bacteria, while others were not.

- *Phytoremediation.* Road-shoulder soil, County of Vejle.

This project has been selected because road-shoulder soil presents a general disposal problem. This project involves extracted road-shoulder soil contaminated with relatively heavy oil products. The county authorities have identified four batches of soil, which either have been or will be deposited in windrows/banks. A preliminary survey of the degree of contamination of the soil is currently being carried out. Relevant soil batches/banks will then be selected for planting.

- *Phytoremediation of soil contaminated by metal.* Valbyparken (Municipality of Copenhagen), Kibæk (County of Ringkøbing), Aakirkeby (County of Bornholm), and Kauslunde (County of Funen).

The four sites were selected because they have different types of metal contamination. In 1998, prior approval was granted to initiate field projects at these sites if a preliminary survey (greenhouse testing) showed potential for remediation. This preliminary project has shown that there is no immediate basis for initiating phytoremediation at some of the sites selected, since the only substance which is absorbed in significant amounts is cadmium, which is a secondary contamination component at the sites. Supplementary analyses have been carried out to determine whether one of the plant types with a large root network could have remediation potential for lead if the roots are harvested as well. It is also being considered whether one of the plants which showed cadmium-accumulating properties is to be grown under open air in order to test cultivation under Danish conditions.

- *Soil leaching.* K.K. Miljøteknik A/S.

K.K. Miljøteknik has a temporary environmental authorisation for using a soil-washing plant and is carrying out a full-scale test on remediation on e.g. soil contaminated by metal. Support has been granted for testing of soil washing at the plant with K.K. Miljøteknik in Rødby. The objective of this project is to test soil-washing techniques on a large scale on various soil types and different contamination types, especially combined contamination, metal contamination, and tar contamination.

- *Modified stripping.* Askov, County of Ribe.

A large site in Askov has been contaminated by chlorinated solvents. Support has been granted to test an "in-well stripping method ", which combines pumping of groundwater by means of the hydraulic-lifting principle and remediation by means of stripping. The stripping system is currently being established, and completion of the project is expected in the year 2000.

- *Modified stripping.* Åbenrå, County of North Schleswig.

A site in Åbenrå has been heavily contaminated by chlorinated solvents. Support has been granted to test an "in-well stripping method" aerator in an aquifer with highly variable groundwater influx and very high contamination concentrations. Among other things, this project is to show the effective radius which can be attained in a low-yield aquifer. The project has been delayed because of unexpectedly large amounts of free-phase contamination which must be removed before the aerator can be installed.

- *Fracturing*. Næstved, County of Storstrøm.

Support has been granted to document the effect of hydraulic fracturing at a site in Næstved which has been contaminated by chlorinated solvents. Two horizontal hydraulically fractured drain and one non-fractured drain have been established at the site. Among other things, this project is to provide documentation for the effect of the hydraulic drains as compared to non-fractured drains.

- *Field analysis*. Alsønderup, County of Frederiksborg.

A new method for determining amounts of passive pore air called Gore-Sorber has been tested at a site which has been contaminated by tetrachloroethylene. This survey shows that among other things, this method is suitable in moraine clay, where traditional active pore-air measuring cannot be utilised. This project has been concluded and will be published at the turn of 1999/2000.

- *Impact on soil environments from steam injection.*

In connection with a technology project in Hedehusene on thermically assisted remediation directed at chlorinated solvents, a project has been initiated for surveying the effects on flora, fauna, micro-organisms, and soil structure. This project is expected to be concluded in 2001.

1.2 Status for field projects initiated in 1998

The following is a brief status report of all the field projects initiated in 1998:

- *Natural attenuation*. Drejøgade, Municipality of Copenhagen.

The current project at Drejøgade has been expanded by supplementary surveys of natural attenuation in the groundwater. The background for expanding the scope of the project is that the results of those analyses which have already been carried out indicate a significant ongoing natural attenuation of the oil contamination found at the site. Moreover, extensive attenuation of tetrachloroethylene to dichloroethylene and vinyl chloride has been identified. This project has been completed and will be published early on in 2000.

- *Steam injection.* Hedehusene, County of Copenhagen.

Support has been granted to carry out a technology project in connection with the County of Copenhagen's extensive remediation by means of steam injection at a site in Hedehusene. The site has been contaminated by trichloroethylene and tetrachloroethylene. The objective of the technology project is to provide documentation for the effect of the use of steam injection as a remediation method, to elucidate any spreading of the contamination during remediation, to elucidate any geotechnical changes caused by the remediation, and finally assessing the total environmental impact in connection with the remediation. The plant is operational and completion is expected by the end of 2000.

- *Modified stripping method*. Ulstrup, County of Viborg.

A large area in Ulstrup has been contaminated by chlorinated solvents. An "in-well stripping method" is being tested in this connection; combining pumping of groundwater by means of the hydraulic-lifting principle and contamination removal by means of stripping. A technology project has been initiated to determine whether this method is more cost-effective than traditional pumping of groundwater and subsequent stripping and the limitations of the method. This project has been completed and will be published in the beginning of the year 2000.

- *Geo-oxidation.* Gram, The Danish Petroleum Industry Association for Remediation of Retail Sites case.

The Danish Petroleum Industry Association for Remediation of Retail Sites has established a geo-oxidation plant at a former petrol station in Gram, where the contamination is expected to be removed by transmitting electricity through the soil. In this connection, a technology-development project has been initiated to provide documentation for the effect of use of geo-oxidation as a remediation method, including effectiveness against MTBE, to examine the risk for increased spreading of contamination, to examine the risk of increased emissions of volatile compounds, and to examine the effect of geo-oxidation on chemical equilibrium in soil and groundwater. A sample-extraction round is yet to be carried out, following which a status report on this technique will be prepared.

- *Reactive permeable walls*. Vapokon, County of Funen.

A technology-development project has been initiated to establish a reactive permeable wall at the Vapokon site. The overall objective of this project is to establish a knowledge basis on the use of a reactive permeable wall for remediation of chlorinated solvents in groundwater. The reactive permeable wall has been established, and extensive monitoring is currently being carried out.

- *ORC.* Varde, the Danish Petroleum Industry Association for Remediation of Retail Sites case.

The Danish Petroleum Industry Association for Remediation of Retail Sites has carried out remediation of a former petrol station in Varde. The source of contamination has been removed. Some residual contamination in the groundwater remains; it is not possible to remove this contamination by traditional means. This residual contamination does not pose a hazard to the groundwater. Plans were made for removing the residual contamination by means of accelerated/forced degradation by adding an ORC (Oxygen Release Compound). However, more detailed studies showed that the actual contamination situation differed from the estimates made, and that adding ORC was not possible. As a result, the project has been redefined to include an assessment of the geo-probe borings. This project will be published at the beginning of 2000.

- *Natural attenuation.* Radsted, the Danish Petroleum Industry Association for Remediation of Retail Sites case.

The Danish Petroleum Industry Association for Remediation of Retail Sites has carried out a remediation of a former petrol station in Radsted (County of Storstrøm). Considerable residual contamination remains. This contamination does not pose a hazard to the groundwater. The Danish Petroleum Industry Association for Remediation of Retail Sites has entered into an agreement with the County of Storstrøm on monitoring that the projected attenuation does in fact occur. In this connection, a technology development project has been initiated with a vie to determining the effect of the attenuation under natural conditions.

- *Reduction of chromium(VI).* Roskilde, County of Roskilde.

A technology-development project has been carried out in connection with a large value-depreciation remediation in the County of Roskilde, where the contaminants included chromium(VI). The objective of the project was to develop a method for reducing the very toxic chromium(VI) to the less toxic chromium(III) in both groundwater and soil. A practicable method for remediation of chromium(VI) in groundwater was developed, whereas this method proved to be less useful against soil contamination. The project on groundwater was published in Environmental Project No. 497. The project on soil remediation will be published early on in 2000.

- *Petrotech*. The Danish Defence Construction Service.

Support has been granted for having the Danish Defence Construction Service test a new product called 'Petrotech' for treatment of soil with oil contamination. The objective of this project is to test whether this project can promote remediation of extracted soil contaminated by oil. The project is to provide documentation for the effect of the product and its limitations, assess any risk involved in the use of the product and provide estimates regarding the cost of this method in comparison with traditional remediation methods. A report is currently being prepared on this project, which will be published early on in the year 2000.

1.3 Status for field projects initiated in 1997

The following field projects received support in 1997 and are still in progress:

- *Airsparging, soil-vapour extraction.* Dry-cleaning business, Drejøgade, Municipality of Copenhagen.

The site is contaminated by oil and chlorinated solvents. A soil-vapour extraction plant and an airsparging plant with horizontal borings were set up in autumn 1997. By the turn of the year 1998-1999, a total of approximately 500 kg oil products, approximately 100 kg tetrachloroethylene, and approximately 10 kg trichloroethylene had been removed. Two status documents have been published, i.e. Environmental Project No. 480 and Environmental Project No. 487.

- *Soil-vapour extraction*. Dry-cleaning business, Waste Deposit 663-15, Ikast, County of Ringkjøbing.

At this waste deposit, which features contamination from tetrachloroethylene, a soil-vapour extraction plant has been established in inhomogeneous sediments. The plant is operational.

- *Steam injection.* Brüel & Kjær, Nærum, County of Copenhagen.

Brüel & Kjær has carried out voluntary remediation by means of steam injection at a site in Nærum. This site was contaminated by chlorinated solvents, as well as by other substances. In connection with the steam-injection project, a technology project has been initiated for a part of the site to provide experience and documentation on the use of steam stripping as a remediation method. A total of approximately 2,800 kg chlorinated solvents (TCE and PCE) has been removed. The project has been concluded and publication is expected at the beginning of 2000.

- *Reactive permeable wall.* Hard-chromium, Kolding, County of Vejle.

A reactive permeable barrier for removal of a groundwater contamination with trichloroethylene and hexavalent chromium Cr(VI) has been established. This project focuses on combining remediation of two different contaminants in the same remediation technology. Measurements carried out over a one-year period show good results for contamination elimination.

- *Iron-filings filtering plant*. Dry-cleaning business, Lyndby, County of Roskilde.

In connection with other remedial measures at the site, a reactive iron-filings filtering plant above terrain level has been established which is connected in series with a carbon-filter plant. The plant processes pumped-up groundwater which has been contaminated by chlorinated solvents. The objective of the plant is to test and dimension an iron-filings filtering plant for removal of chlorinated solvents. This removal takes place as a result of reactions on the iron surface. Full-scale experience regarding iron-filings filtering is achieved by carrying out detailed monitoring of removal rates and the governing factors. The plant has been established.

- *Dual-phase extraction.* Dry-cleaning business, Haslev, County of Western Zealand.

Surveys of the site show considerable contamination from chlorinated hydrocarbons, primarily tetrachloroethylene, from a dry cleaning business. Additional surveys and sketch projections have been performed to assess the opportunities for carrying out remediation either by means of soil-vapour extraction or by means of dual-phase extraction. The results of the surveys and the sketch project show that it is probably not possible to carry out remediation by means of dual-phase extraction at the site. The county is expecting to initiate a project utilising hydraulic fracturing combined with dual-phase extraction. A fissure analysis has been carried out on the moraine clay in a nearby excavation with a depth of seven metres.

- *Accelerated/forced leaching*. Hjørring Gasworks, County of Northern Jutland.

In connection with the gasworks programme, a test project was established at Hjørring Gasworks which comprises accelerated/forced washing and circulation of groundwater to

increase the microbial degradation of tar substances. This project is being continued under the Technology Programme. The objective is primarily to obtain more detailed documentation for the degradation processes and documentation of how washing and degradation can be optimised. Operation and surveying is currently being carried out.

- *Elektrodialytic remediation.* DTU.

The electrodialytic method for remediation of soil from wood-impregnation sites is being developed and tested. At laboratory level, remediation testing has been carried out of sandy soil to determine process parameters (power level and addition of reagents) and the expected effectiveness. This will be followed by test remediation at a pilot plant of the same soil type as well as moraine clay. The test results will form the basis for a description of various significant soil parameters. The suitability of this method - in-situ and on-site - and the total environmental impact from a full-scale remediation will be assessed.

2. Desk studies

The following desk studies have been carried out during the period since 1997:

- Remediation of soil contaminated by heavy metals.

Environmental Project No. 407, 1998.
This report reaches the conclusion that it will be relevant to test the following methods: extraction by means of plants, electrokinetics, and soil washing.

- Natural attenuation of xenobiotic substances in soil and groundwater.
  Environmental Project No. 408, 1998.

The main objective is to provide an assessment of which substances are considered degradable in nature under predetermined redox conditions. The method used for determining each degradation rate for substances is given, for example, in the laboratory by means of soil-sample tests or batch tests, in situ tests, or by means of field testing.

- Thermically assisted remediation.

Environmental Project No. 409, 1998.
This report describes various methods where remediation is supplemented by soil heating.

- Soil-vapour extraction cases from the Danish Petroleum Industry Association for Remediation of Retail Sites.

Environmental Project No. 421, 1998.
This project describes the experience gathered from remediation projects which the Danish Petroleum Industry Association for Remediation of Retail Sites have carried out by means of soil-vapour extraction.

- Remediation techniques for groundwater contaminated by MTBE.

Environmental Project No. 483 1999.
On the basis of a survey of literature in international databases, descriptions are being prepared of the methods which are expected to be usable for remediation of groundwater with MTBE contamination.

- Assessment of the pulsed-vapour-extraction remediation technique.

Environmental Project No. 491, 1999.
This project describes two techniques where compressed air is forced down into contaminated soil or landfill deposits by means of pulses.

- Experience from the Gasworks Scheme.

Environmental Project No. 492, 1999.
This project compiles the results from the five test projects which have been carried out during the period from 1990 to 1993 under the auspices of the Danish EPA 'Gasworks Scheme'. This project provides an overview of the remediation techniques used, the basis for selecting the techniques, assessment of the results, recommendations, and cost.

- Remediation methods directed at combined contamination.

Environmental Project No. 503, 1999.
A systematic survey of possible remediation methods has been carried out to form a basis for assessment of the need to develop methods for remediation of soil with combined contamination and tar/PAH contamination. Soil washing, electrokinetics, phytoremediation, and stabilising have been examined with a view to processing soil with combined contamination, whereas thermic processing, biological processing, extraction, and wet oxidation have been examined to remediate soil with tar/PAH contamination. Finally, the suitability of these methods under Danish conditions has been debated

- Natural attenuation of PAHs in soil and groundwater.

A desk study has been carried out on the basis of a survey of existing literature to determine the current status of knowledge on this subject.

- LIFE project on environmentally appropriate remediation.

The Danish National Railways Agency has initiated a LIFE project (under the auspices of the EU) on environmentally appropriate remediation of 5 sites contaminated by oil and/or chlorinated solvents. Support has been granted through the Technology Programme funds for this project. The objective of the project is to achieve effective and optimum remediation of soil and groundwater at sites which are contaminated by oil and/or chlorinated solvents. This project will see the development of a model for decision-making in environmentally appropriate assessment when selecting the best remediation technique in any given situation. In addition to this, work will be carried out to optimise the remediation techniques used (air sparging, both horizontal and vertical borings, soil-vapour extraction, stimulated attenuation, reactive permeable walls). This project will be completed in 2000.

- Development of in situ techniques for microbial degradation of PCB, TCE, and PAH in soil.

This project is being carried out as a collaboration between Denmark and research institutions in Ireland, Spain, Germany, and the USA. The objective of the project is to develop a technique which utilises a combination of plant roots and micro-organisms for degradation of contamination in soil. This technique is based on the use of plants with wide-ranging root systems, such as alfalfa and willow, for spreading degrading bacteria in the soil. The types of bacteria selected will normally colonise plant roots and have been genetically modified for attenuation of the organic contamination, which is otherwise difficult to combat.

- Fracturing methods.

A desk study describing various methods of fracturing has been carried out, with special focus on using these methods in Danish conditions. The results of this project will be published at the beginning of 2000.

- Phytoremediation for soil contaminated by oil/petrol.

A survey has been carried out of literature regarding the ability of willow and other plants to clean up organic compounds (oil/petrol). This literature now forms the basis for field projects on remediation by means of willow and other plants. The results of this project will be published in mid 2000.

- Risk assessment of gas-producing landfills.

A project regarding preparation of guidelines for survey and risk assessment of gas-producing landfills has been initiated. The risk comprises explosion hazards in buildings situated near landfills with organic waste which produces methane upon degradation. The results of this project will be published in mid 2000.

- Absorption of metals and PAH in fruit and vegetables.

A desk study has been initiated in collaboration with the Municipality of Copenhagen and the County of Northern Jutland on absorption of metals and PAH in fruit and vegetables. A series of selected vegetable types are being grown in beds in Valbyparken. These beds comprise three types of soil: clean soil, soil with diffuse contamination, and heavily contaminated soil. Analyses for metals and PAH are being carried out. Fruit which has been harvested in Copenhagen in allotment gardens with varying degrees of contamination is

being analysed for metals, and fruit harvested from clean sites and sites contaminated by tar in Skagen is being analysed for PAH. Cultivation and harvesting was done during the summer of 1999.

- Assessment of demarcation nets and geo-textiles.

An assessment is being carried out of the suitability of the various types of demarcation nets and geo-textiles available on the market for the purpose of separating contaminated and clean soil. The results of this project will be published at the beginning of 2000.

3. Other projects on soil contamination

The following other projects on soil contamination have been initiated under the Technology Programme:

- Spreadsheets for risk assessments.

The Danish EPA has issued guidelines for counties and local authorities on remediation of contaminated sites. The methods featured in these guidelines for risk assessment in relation to air and groundwater contain a series of complicated formulae which in practise will be most useful using a spreadsheet. Consequently, a user-friendly spreadsheet tool has been developed.

- Statistic 3D calculation of the probability of finding soil contamination.

Environmental Project No. 449, 1999
This project describes a method for calculating the probability of finding soil contamination by means of borings where soil samples are extracted. The approach, process and preconditions are described, and the method is illustrated by means of a sample calculation. This method can be used for contamination which has not necessarily spread from terrain level, and where determination of the location of the contamination depends partly on the location of the borings, and partly on their depth.

- The Danish Standards Association.

In collaboration with the Danish Standards Association, support has been granted for Danish participation in the international working group ISO/TC 190/SC 7/WG 2 'Soil quality - Soil and Site Assessment; Characterisation of Soil related to Groundwater'. This working group is currently preparing standards for risk assessment of groundwater. Had Denmark not participated in this project, it is likely that the resulting standard would not comply with normal Danish practise on risk assessments, cf. the Danish EPA guidelines on remediation at contaminated sites.

- The Danish Standards Association.

Support has been granted for Denmark to assume presidency and secretariat functions for the international subcommittee for standardisation of the area designated as ISO/TC 190/SC 5 'Soil Quality – Physical Methods'.

- Systematisation of data on diffuse contamination, phase 1.

In collaboration with the Information Center on Contaminated Sites, a project has been initiated to collect and process existing data from surveys of airborne diffuse contamination in urban areas and along roads in order to improve general knowledge within this area. This project has been concluded, and the results will be published early in 2000.

- Leaching of organic substances.

The Danish EPA expects to issue a statutory order on recycling and reuse of residues and soil. This order sees the introduction of batch-leaching tests as the principle for determining contamination in soil. The data available and previous experience on leaching tests for soil are limited in scope. The objective is to optimise leaching tests and to carry out a survey - both in theory and practise - for these test with regard to organic contamination for a wide variety of soil types.

- Characterisation of soil with metal contamination.

The objective of this project is to provide better knowledge of leaching of metals from soil and residues. These surveys are partly to include uncontaminated soil and contaminated soil types, as well as two types of residue. The results are to form the basis for evaluation of a batch-leaching test of the same soil types. Batch-leaching tests form a significant element in the future regulation on rendering soil usable for building and construction work.

- Improving tests and the basis for data .

Tenders have been invited for a project to improve knowledge of the factors which affect the results of leaching tests in relation to leaching of trace elements and metals from soil. A series of representative samples of uncontaminated and contaminated soil is to be collected, and more comprehensive data material for leaching of substances is to be prepared, possibly using improvements to this test. By collecting and testing samples of various soil types (loam, sandy loam, clay, and sand), it is hoped to obtain knowledge of background contents and background leaching of Na, K, SO_4^{2-},Cl, Ca, As, Cr, Cd, Cu, Ni, Pb, Al, and Zn.

- Determination of contamination contributions to indoor climates.

When carrying out assessments of the need for remediation in order to improve indoor climates on contaminated sites, there is a lack of methods to determine the contamination contributions from soil and groundwater. Situations can occur where remedial measures are initiated to improve indoor climates without any conclusive evidence documenting a connection with the contamination of the soil and groundwater. Because of this, a method will be developed to determine contributions from soil and groundwater contamination to indoor climates.

- Analysis method for PAH contamination of soil.

Tests have shown that there is a great need to develop a standard method for analysing PAHs in soil, and to identify suitable reference materials. Moreover, regarding stipulation soil-quality criteria for PAHs there is a need to establish a suitable method of analysis so that the soil-quality criteria for PAHs are related to a given method of analysis. The objective of this project is to develop such a method.

- Processing and presentation of mapping data from the County of Northern Jutland.

The European Environmental Agency wishes to collect data on contaminated soil in Europe. However, mapping is being carried out at very different levels within the various countries, and the assessment criteria used are also different. Data from the County of Northern Jutland have been processed in accordance with a predetermined standard form so that the opportunities for comparison can be assessed. Seven other countries are also participating in this project.

- Chemical profile of the composition of oil and petrol

The composition of oil/petrol is described. This description is to be used for risk assessment of soil contamination in relation to evaporation and groundwater resources.

- Model analysis of remediation by means of steam injection

The objective of this project is to carry out a model analysis of processes and operating conditions which influence the effectiveness of steam injection, and use this analysis as a basis for developing simple and operational models for design purposes.

4. The following projects have been published:

As of 1 December 1999:
No. 407: Remediation of soil contaminated by heavy metals.
No. 408: Natural attenuation of xenobiotic substances in soil and groundwater.
No. 409: Thermically assisted remediation.
No. 421: Soil-vapour extraction cases from the Danish Petroleum Industry Association for Remediation of Retail Sites.
No. 449: Statistic 3-D calculation of the probability of finding soil contamination.

No. 480: Airsparging and vacuum-vapour extraction from horizontal borings at Drejøgade 3-5: Design and plant construction.
No. 483: Remediation techniques for groundwater with MTBE contamination.
No. 487: Airsparging and vacuum-vapour extraction from horizontal borings at Drejøgade 3-5: Status report.
No. 491: Assessment of pulsed vapour extraction and pneumatic fissuring.
No. 492: Summary report of the Gasworks Scheme.
No. 497: Reduction of chromium(VI) in groundwater by means of iron filings.
No. 503: Combined contamination.

5. Expert secretaries

The following persons have agreed to be expert secretaries:

- Thomas H. Larsen, PhD, Hedeselskabet - air sparging and passive vapour extraction.
- Peter Kjeldsen, PhD, DTU - reactive permeable barrier.
- Bjørn Jensen, MSc, VKI - soil-vapour extraction.
- Ulrich Karlsson, PhD, DMU - phytoremediation.
- Civ. Engineer Poul Løgstrup Bjerg, PhD, DTU - ORC and natural attenuation.
- Tom Heron, MSc, NN&R - thermically assisted remediation and geo-oxidation.

Appendix B

MILJØ & ENERGI
MINISTERIET
THE DANISH EPA

Paradigm for pledge for support for field projects.

Recipient
ATT.:

The Soil Contamination Division

File No. M
Ref. /14

Re.: Technology Programme. (site, city, county).

Date

In accordance with Section 8 a (2) of the Ministry of Environment and Energy Consolidated Act No. 939 of 27 October 1996 on Waste Deposits and Landfills, the Danish EPA shall issue a pledge for support amounting to a total of DKK (xxxxxx), not including VAT, corresponding to DKK (xxxxxx) including VAT for testing of (xxxxxx) technology under the Danish EPA Technology Development Programme. The following features more detailed specifications for such support.

The pledge issued for support and any support already paid may be revoked if the recipient does not continue to fulfil the conditions for receiving support or is incapable of carrying out activities in a satisfactory manner.

Encl.

The recipient is requested to sign and return the enclosed letter of acceptance to the Danish EPA.

1. Project title, project description and project period.

Encl.

The title of the technology project is (xxxxxxx). The project description shall be prepared by (consultant) on (date and year) with assistance from the expert secretary (xxxxxx).

This sketch project (this does not always apply) features outlines of proposals for establishing (method) at the site. It also features more specific detail on project objective, contents, funding, time schedule, etc.

The overall objective of the technology project (which will differ with each project) is to bring about a knowledge base with regard to use of (the method), including:

- Provision of documentation for the effect of the use of (the method) as a remediation method under the specific geological conditions and environmental chemistry, including the limitations of the method.
- Selection of the key parameters for dimensioning and monitoring.
- Preparation of guidelines for establishing, operating, monitoring, and completing remediation by means of (method).
- Provision of an estimate of the costs of using the method.

(The recipient) shall hold the legal status of developer and shall thus carry out negotiations with a consultant as well as prepare contracts, etc.

The Danish EPA grants support for testing technology and has no knowledge as to the applicability of the technology in specific cases. Thus, the Danish EPA cannot be held responsible for the results of such testing.

The project will be initiated on (date and year) and completed on (date and year).

2. Budget, payments, etc.

The total budget has been calculated at DKK (xxxxxx) not including VAT.
The Danish EPA shall contribute DKK (xxxxxx) not including VAT,
(The recipient) shall contribute DKK (xxxxxx) not including VAT.

The total support has been calculated at (xxxxxx) DKK, not including VAT; which corresponds to DKK (xxxxxx) including VAT.

The budget is described in more detail in the enclosed project description - however, the support includes costs in connection with HTML coding of the report to a total of DKK (xxxx) not including VAT.

(The two sections below shall be included or omitted as appropriate for the project)

Encl. The support includes an amount of approximately (xx) per cent of the total cost, corresponding to DKK (xx) not including VAT, for contingencies.

The contingencies of (xx) per cent can only be used upon agreement with the Danish EPA.

The costs are distributed amongst individual financial years as follows:
2000: (xxxxxx) DKK not including VAT
2001: (xxxxxx) DKK not including VAT
2002: (xxxxxx) DKK not including VAT (contingencies are included here)
- to be deleted if previous sections on this subject have been omitted

The recipient shall assume liability in relation to subcontractors. This includes responsibility for ensuring that contracts are entered into on terms (with regard to price, guarantees, complaints, and liability) which in view of the circumstances are usual and advisable according to expert assessment, that contracts are entered into in accordance with normal business terms, and that contract amounts do not exceed budgeted amounts.

When the Danish EPA has acknowledged that the technology project has been completed, (the recipient) shall take over the plant and all appertaining installations, provided that the equipment is deemed to have been depreciated to a value of DKK 0 at this time.

The Danish EPA shall also require that equipment which has been acquired by (the recipient) with funds granted by the Danish EPA be registered by (the recipient's institution).

3. Project management.

(The recipient) shall be responsible for ensuring that the project is completed within the framework stipulated for timing and funding.

In the event of any problems, such a financial, technical, or time problems, the person responsible for the project shall submit a written proposal for resolving this problem to the Danish EPA.

(The recipient) shall be responsible for securing any equipment.

The contact person and project manager appointed by (the recipient) are (xxxxxx).

The contact person(s) appointed for the Danish EPA are (xxxxxx). Any amendments to the project and the organisation shall be authorised by (the recipient) and the Danish EPA.

A steering committee for the technology project shall be set up, with (xxxxxx) from (the recipient) as chairman. The steering committee shall also include the expert secretary, the consultant, and (xxxxxx) from the Danish EPA.

The steering committee shall be responsible for:

- ensuring that the project is carried out according to plan,
- carrying out regular assessments of the progress and results of the project,
- deciding on any adjustments to the plans regarding the project,
- ensuring that the project is coordinated with other projects, if necessary,
- approving the result of the project, and
- ensuring compliance with the financial framework.

4. Copyright.

(The recipient) and the Danish EPA shall have joint copyright for the results of the project.

The Danish EPA shall hold all electronic publishing rights regarding the products specified in this contract; this includes copyrights on illustrations, etc.

5. Publication.

After completion of the project, (the recipient) and the Danish EPA may use and publish the results of the project as they see fit.

The project shall be concluded by a final report, which is prepared in accordance with the detailed guidelines issued by the Danish EPA: 'Fra manuskript til publikation – gør Miljøstyrelsens publikationer klar til tryk, oktober 1999' ['From Manuscript to Publication - Preparing Danish EPA Publications for Printing, October 1999'] and 'Publikationers klargøring til elektronisk publicering, Vejledning 1998' [Preparation of Publications for Electronic Publication, Guidelines 1998], cf. the design guide and guidelines through the Danish EPA homepage at: http://www.mst.dk/fakta/40000000.htm.

The project report shall be ready for printing and electronic publication. The report shall be submitted in the Word ’97 format on a diskette or CD-ROM and as a hard copy, and must be submitted as one document.

The Danish EPA must be approached in connection with electronic publication (HTML coding) in order to determine the actual coding process.

(The following section shall be included or omitted as appropriate)
Upon completion of the project, the advisor shall submit a project article in Danish and English versions, each of which shall be ready for publication as separate units. The project articles shall be written in accordance with the guidelines issued by the Danish EPA, cf. attachment, and be ready to be published electronically. Project articles which are to be printed shall be submitted in a Word '97 format as hard copies and in file format on a diskette.

All materials to be used for publication shall be proof-read upon submission.

Part one of the enclosed publication form shall be filled in by the person(s) carrying out the project and shall accompany the project report and HTML version.

As far as possible, all of the above shall be submitted collectively to the Danish EPA.

6. Settlement and payment.
Settlement shall be carried out annually to (the recipient) on the basis of detailed accounts. For settlement of projects valued at less than DKK 100,000 not including VAT, copies of documentation for the specified costs shall be enclosed, including time records.

When finalising the accounts, detailed final accounts for the entire project period shall be available. According to the terms of pledges for support, final accounts (greater than DKK 100,000 not including VAT) shall be audited. Where the end accounts exceed DKK 100,000 not including VAT, they shall include an auditor's report, and where they exceed DKK 500,000 not including VAT, the auditor shall be a registered public accountant or a state-authorised public accountant. Expenses for the audit shall be paid by the recipient.

The Danish EPA is currently preparing audit instructions for the support scheme. Until these instructions are available, audit shall be carried out in accordance with good audit practise as described in the enclosed model instructions for project support issued by the Office of the Auditor General of Denmark. The Danish EPA will distribute the audit instructions for the support scheme when they become available.

Reimbursement from the Danish EPA also requires submission of a completed status form with the receipts; this form is to be filled out in accordance with the Danish EPA guidelines, cf. the enclosed.

Invoices for work carried out within a given financial year shall be with the Danish EPA no later than 10 January following the end of the said financial year. Invoices which are submitted later cannot be expected to be reimbursed by the Danish EPA in that year.

Overruns due to increased prices, salaries, and consumption will not be reimbursed by the Danish EPA unless a prior supplementary written agreement to this effect has been entered into.

Best regards

Enclosed documents:

- Project description, dated on [ ] and project budget
- Status form (must be enclosed with each settlement).
- "Forfattervejledning - for projektartikler til Miljøstyrelsens magasin Ny Viden" ['Author's Guidelines - for Project Articles for the Danish EPA Journal "New Knowledge"'].
- Publication form (part 1 shall be filled in by the person carrying out the project).
- Model instructions for audit of support.
- Letter of acceptance of support.

Appendix C

Paradigm

Framework for description of field projects:

- Background (brief section describing the programme).

- The objective of the technology project at the specific site (overall objective).

- Description of the site, including:
  - Geological conditions.
  - Contamination conditions.
  - Any remedial measures taken outside the scope of the technology project.
  - Other conditions and circumstances.

- Description of the technology project:
  - Activities, which are carried out as part of the detailed planning process, including additional surveys, borings, etc.
  - Activities which must carried out prior to and when establishing plants or carrying out similar measures.
  - Activities which must carried out during operation of the plant (test measuring, analysis results, observation, etc.).
  - Activities which are to be carried out to monitor the project.
  - Reporting on the technology project - both during and upon completion of the project.

- Time schedule.

- Financial estimates:
  - For each element of the technology project (see budget).

- Staffing (including the steering committee).

- References.

Appendix D : Paradigm for budget 1

Technology project: **Enclosed documents:**

Prepared by:

Date: Audit date:

Description	**Recipient contribution DKK not including VAT**			**Sum**	**Support granted by the Danish EPA DKK not including VAT**			**Sum**	**Total sum** Recipient contribution + Danish EPA support
	Consultant		Contractor		Consultant		Contractor		
	Fee	Disbursem.			Fee	Disbursem.			
Detailed planning									
- surveys									
- borings									
- report									
- other									
Total detailed project									
Construction stage									
- construction of									
- borings.....									
- pumps....									
- report									
- other									
Total construction									
Operation									
- analyses									
- observation									
- reports									
- other									
Total operation									
Completion									
- borings									
- other									
Total completion									
Total for recipient Contribution – DKK, VAT not included									
Total for support from Danish EPA – DKK, VAT not included									
Total for total project - DKK not including VAT									
Total for total project - DKK including VAT									

Paradigme for budget 2: In-progress budget amendments

Technology project: **Enclosed documents:**

Prepared by:

Date: Audit date:

Description	**Total budget as at (date)**				**Basis for distribution as at (support date) DKK not including VAT**		**Variance in relation to the total budget as at (support date) DKK not including VAT**	
	Number of consultant hours	Fee DKK not including VAT	Disbursement DKK not including VAT	Sum DKK not including VAT	Support granted by the Danish EPA	Recipient contribution	Support granted by the Danish EPA	Recipient contribution
Detailed planning								
- surveys								
- borings								
- report								
- other								
Total detailed project								
Construction stage								
- construction of								
- borings.....								
- pumps....								
- report								
- other								
Total construction								
Operation								
- analyses								
- observation								
- reports								
- other								
Total operation								
Completion								
- borings								
- other								
Total completion								
Project total DKK not including VAT								

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