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# Environmental Hot Spot Remediation:

## The Czech Experience

MINISTRY OF THE ENVIRONMENT
OF THE CZECH REPUBLIC

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# Preface

Hot spots – ecological sites that became contaminated during the Soviet period – pose a serious health risk to those who live near them, either because of their direct impact on human health or their potential to poison the food chain. Unfortunately, many countries in Central and South-Eastern Europe and the Commonwealth of Independent States (CIS) have no procedure for cleaning up these hot spots, which resulted largely from heavy industrialization during the Soviet period. The number and severity of these contaminated sites are not known; the clean up costs have not been estimated; funding is largely unavailable; and the "ownership" of these environmental burdens post privatization is not clear.

This publication focuses on the experience of the Czech Republic in assessing and cleaning up hot spots. It presents tools for decision-makers, industrial site managers and consultants in addressing environmental hot spots.

The United Nations Development Programme (UNDP), the Czech Ministry of Environment, the Czech Ministry of Foreign Affairs (Czech Trust Aid) and environmental experts have cooperated closely on this publication. The objective is to transfer the experience and lessons learned in the Czech Republic to other countries in Central and South-Eastern Europe and the CIS. Management of ecological damage requires a partnership both at the national and international level. It also calls for new research and innovative approaches.

*Ben Slay*
*Director of the Regional Centre UNDP, Bratislava*

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# 1. The Czech Experience and its Application to Other Countries

Throughout the Newly Independent States (NIS) and Central and Eastern Europe (CEE), decades of heavy industrialization and extensive exploitation of natural resources have left many areas in the region heavily polluted. Over the past decade, these countries have moved from centrally planned economies, with government ownership and management of the means of production, towards free market economies, with varying levels of privatization. As these countries transition to private ownership, it is essential that old environmental burdens left behind by state-controlled industry be addressed: problems which were once (theoretically) the government's have now been transferred over to new owners, in most cases without any clear indication of responsibility.

Old environmental burdens (hot spots) in the region represent a serious risk for humans who live in or near contaminated areas because of either their direct negative impact on the human health or, indirectly, through pollutants in the food chain production. Currently, most countries in the region have no systematic method for addressing and remediating these environmental hot spots; their number and severity are not known, clean up cost is not systematically estimated; funding for the most part is unavailable; and even "ownership" of these environmental burdens in a post- privatized setting is not clear.

In the NIS/CEE region, the experience of the Czech Republic in addressing old environmental burdens has been unique. In 1992, at the very outset of the privatization process, the Czech Republic began a process to address old environmental "hot spots" by establishing a state-supported system for their assessment and remediation. The driving force behind this was the privatization process and the Government's commitment to support new owners of sites with environmental damages caused prior to privatization. For this purpose, the Government authorized the National Property Fund (and, for agricultural land, the Land Fund) to manage a special account with funds up to the purchase price of the privatized state property. This account can be used for at least partial reimbursement of costs for elimination of environmental damages. The Government approved additional funding for remediation of former Soviet Army sites and for revitalization of former mining regions and other brownfields.

The decade-plus Czech experience includes the development of legal, institutional, financial and methodological processes as well as managerial and professional capacity building and technological research and development. The Czech experience—both its successes and failures—is worth being shared. Important steps have been made towards dissemination of the Czech transition experience to other countries through the transfer of professional know-how and innovative technologies.

The goal of this publication is to further transfer and share the Czech experience in developing a systematic approach to addressing old environmental burdens in the NIS/CEE region. The publication first provides an over-view of the legal and institutional basis and financial mechanism that were developed to regulate and support the process in the Czech Republic and highlights the importance of clearly delegated lines of authority and responsibility. The publication next outlines the steps in the remediation process itself: the methodological guidelines and relevant regulations that guide the Czech system. Finally, it provides two case studies that highlight the application of the Czech system in real-life cases. Drawing on the Czech experience, the publication provides practical examples of institutional arrangements for addressing environmental burdens for policy makers, consulting companies and owners of private companies in the NIS/CEE region.

# 2. The Czech System and Procedures for Hot Spots Remediation

The Czech experience in the assessment and remediation of past environmental damage is driven by an ongoing process of widespread privatization coupled with the need to address problems of historical environmental liabilities. After the collapse of the Soviet state-controlled economy, environmental burdens resulting from 40+ years of state controlled ownership of the means of production were transferred to new, private owners. The magnitude and seriousness of these burdens, however, was beyond the scope of what private owners could deal with on their own and required the development of a republic-wide system of assessment and state-supported remediatation. The Czech experience is unique in its systematic, national approach and in that it was put in place at the initial outset of the privatization process.

The framework of this new environmental policy to address environmental burdens in the Czech Republic, including significant financial support, has accelerated the growth of the Czech "environmental market". The high level of Czech geology, hydrogeology and engineering professionals was a positive precondition in this regard. On the other hand, lack of practical experience in effective environmental management presented a serious obstacle. These factors influenced new approaches in environmental protection in the Czech Republic and exposed both strong and weak points of remediation techniques and technologies and of the decision-making process as well.

In acquiring experience in solving various types of practical problems at hundreds of environmentally damaged sites in the Czech Republic, it became clear that a regulatory framework, a systematic approach and clear responsibilities within the decision-making process are crucial factors for effective identification, assessment and remediation of environmental damages. Moreover, it is necessary to adopt the right policy incentives and to establish a viable funding system. In the Czech Republic, the main accelerator was the privatization process (a need to support new development of Czech industries) and the departure of Soviet Army troops (a need to revitalize the abandoned areas).

## 2.1 Legal Framework

Based on the above preconditions, the clean-up process of past environmental damages in the Czech Republic was launched by adopting a series of environmental and privatization laws and specific Government resolutions concerning contaminated land (See Appendix I).

## 2.2 Institutional Framework

In addition to a solid legal framework, a second essential step was the establishment of clear responsibilities of relevant institutions and other stakeholders.

At present, there are two key institutions dealing with managerial issues of hot spots assessment and remediation: the National Property Fund of the Czech Republic (NPF) and the Ministry of Environment (MoE). Another important institution is the Czech Environmental Inspection (CEI) agency, an independent authority responsible for setting and controlling remediation targets and criteria.

Other institutions enter the process according to their competencies and responsibilities laid out in legal frameworks (e.g., building authorities, water protection authorities, authorities dealing with waste management, mining authorities) or according to their professional status (e.g., the Czech Geological Survey and the State Health Institute, which work as advisory bodies for the MoE).

The new owner of the contaminated site is legally responsible for remediation but may apply for reimbursement of the remediation costs.

Involvement of other private actors (remediation, engineering or consultancy companies and independent experts) is conducted mostly by public tenders published at different stages of site assessment or the remediation process. Among them, the role of independent inspectors working for either the NPF or the MoE is important. Their task is to guarantee the effectiveness and efficiency of operations from the professional point of view.

## 2.3 Funding Mechanism

In addition to the legal and institutional frameworks, another necessary precondition is the establishment of a viable funding mechanism. State guaranties for past environmental liabilities in privatized state companies correspond to the purchase price of the privatized properties and form the upper limit for possible reimbursement of site assessment and remediation costs. These funds belong to the Ministry of Finance and are administrated by the NPF.

In specific cases of contaminated sites that cannot be remedied through the environmental liability agreement (or directly by the polluter), there are some limited funds for regional authorities, guaranteed by the Water Act.

The funds for former Soviet Army sites remediation are covered directly from the State Budget (Chapter 315 - Program of remediating damage left by the Soviet

Army). These funds have some specific requirements, e.g., estimated costs and contracts for specific projects must be approved for each year.

Other funds are approved directly by the Government for regional programs of revitalization, mostly in former mining areas and other brownfields.

## 2.4 Remediation Procedures

Another important step is the development of sound remediation procedures. A simplified version of the Czech system for a typical case for privatized property is as follows:

a) An "ecological audit" provides the initial identification and description of probable environmental damages. The site owner covers the costs for an ecological audit.

b) Evaluation and approval of the audit by the MoE, the CEI and the NPF and submission to the Czech Government for approval by resolution. If approved, the site owner and the NPF sign an "environmental liability agreement". Once signed, all consequent steps are to be financed by the NPF.

c) A "risk assessment[1]" and its "peer-review" by an independent expert or company, followed by MoE, CEI, and NPF approval. If necessary or required by the MoE, a specific statement is prepared by the Czech Geological Survey or by the State Health Institute before final approval. The results of the risk assessment must be included into the "database of past environmental damages" (See Section 3.2 regarding this database).

d) A "remediation order" issued by the CEI, which describes the site owner's responsibility for site remediation, including target criteria and a defined time schedule. If relevant, it also prescribes a specific remediation method.

e) Preparation of "remediation project design terms of reference" (TOR). This is a facultative step, especially in more complicated cases. TOR preparation can involve an in-depth field survey (in order to specify or verify the input data) and either a feasibility study or a cost-benefit analysis (or in some cases, both) for specific remediation options. A TOR will sometimes involve an environmental impact assessment (E.I.A.) as well. The TOR must be prepared by an expert body chosen by a public tender and must undergo peer review by an independent expert or company. The TOR must be approved by the relevant institutions (MoE, NPF, site owner, CEI, local authorities). The results of the field survey must be inputted into the database of past environmental damages.

f) Selection of the best appropriate "remediation project proposal" through a public tender, elaboration of the "implementation project" and its approval by the NPF and by all other relevant authorities according to their legal requirements and competencies.

g) Selection of the supervisory body (either an independent expert or an organization) by means of a public tender, and preparation and approval of the "supervisory project".

h) "Remediation and supervision", including monitoring and reporting, including regular control meetings with all key stakeholders (site owner, remediation company, supervisor, MoE, CEI, NPF and local authorities when appropriate). The results must be annually inputted into the database of past environmental damages.

i) "Verification that target criteria were met" and "protocol on remediation accomplishment" issued by the CEI. The verification is often complemented by an "updated risk assessment" (with the same rules and procedures as during elaboration of the original risk assessment).

j) An "order on post-remediation monitoring". The CEI defines the scope of the post-remediation monitoring, the location of the sampling site(s), the time frames, frequency of data collection and the scale of chemical analyses. Alternatively, these requirements can be set in the original CEI order when appropriate.

k) "Post-remediation monitoring and supervision", with regular reporting and control days. The results must be annually inputted into the database of past environmental damages.

l) Final accomplishment of remediation process and "termination of environmental liability agreement" with the NPF.

## 2.5 Methodological Framework

The large number of contaminated sites identified during privatization called for clear guidelines, methodologies and recommendations which would facilitate data collection, data processing and the decision-making process. The following guidelines are among the most relevant:

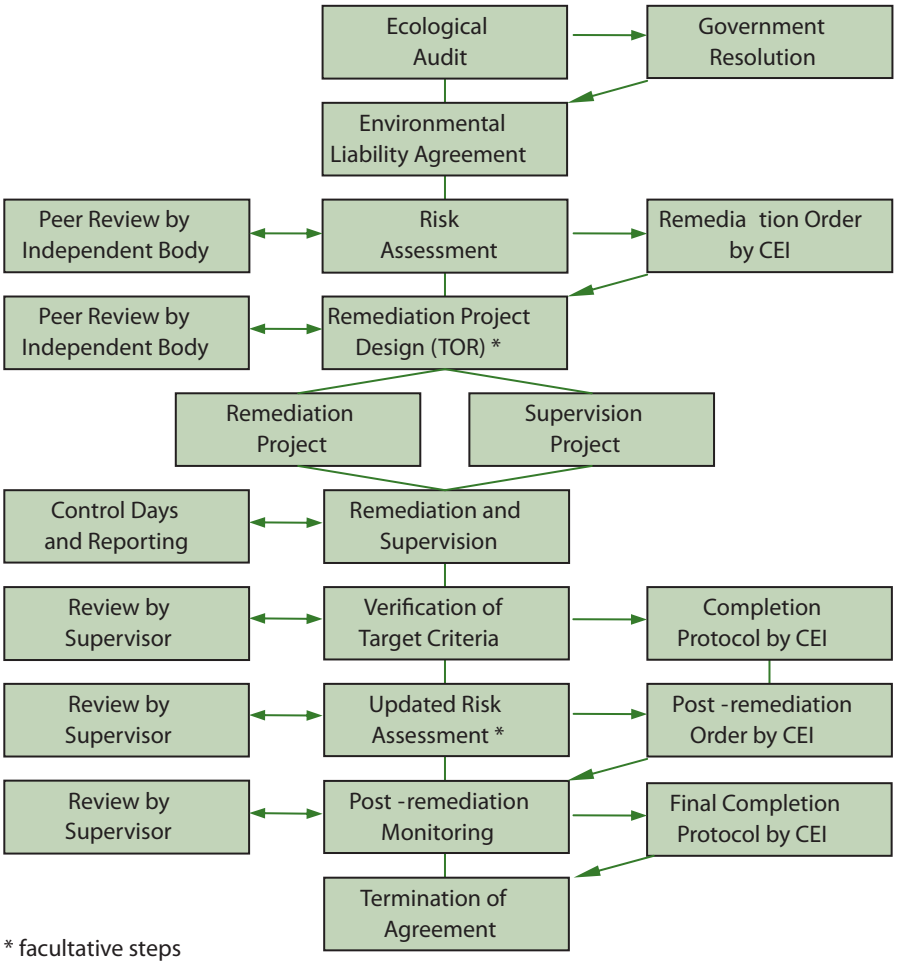
- Ecological Audit – an initial assessment of environmental damages; ongoing pollution sources must be distinguished. The requirements for ecological audits were set in 1992 by the Ministry for Management of National Property and its Privatization and consisted largely of desk studies. The current approach is more compatible with auditing within the implementation of environmental management systems and more stress is given to verification of input data by a field survey.
- Risk Assessment – an evaluation of current risks and consequences of historic contamination. The requirements were set by the MoE in methodology guidelines in 1996; an update is currently under preparation.
- Soil, Water and Soil-Gas Contamination Criteria – the setting of auxiliary comparative limits for the needs of decision makers. The criteria from 1996 mostly follow the Dutch list and should not be used as obligatory

[1] Section 3.1 on risk assessment provides additional information.

parameters for remediation but only as indicators for designing follow-up activities of field survey and risk assessment.

- Atmogeochemical Survey – an introductory guideline on detection of organic contaminants in soil-gas as a screening method for soil contamination assessment. A draft guideline was prepared by the MoE in 1998.
- Supervision on Remediation Activities – a set of several guidelines issued by the NPF and the MoE between 1996 and 1998. The methodology defines principles for checking effectiveness and efficiency of remediation projects.
- Geophysical Survey – a review of geophysical methods and their possible applications during contaminated site assessment. It was published by the MoE in 1999.
- Quality Management of Field Survey Methods – a draft proposal from 1997, summarizing requirements on sampling different media, from survey design to chemical analyses. The requirements are compatible with the Czech and European technical norms and follow the quality management criteria. An update is currently under preparation; the new guideline should be complementary to the new guideline on risk assessment.
- Quality Management of Remediation Methods – a review and characterization of the most frequent as well as of innovative remediation methods, including a comparison of their strengths and weaknesses. The guide was published by the MoE in 2000.
- Natural Attenuation of Petroleum and Chlorinated Hydrocarbons – a review of basic principles and up to date experience with alternative remediation. The guide was published by MoE in 2001.
- Database of Past Environmental Damages – a central register of contaminated sites, including Geographic Information System (GIS) data, operated by the MoE since 1996. Any contractor of the MoE or the NPF working in the field of contaminated sites is obligated to insert data by the end of the contract (risk assessment, field survey, TOR for remediation) or annually (remediation, supervision).
- Regional Priority List of Environmentally Damaged Sites – an indicative review of priorities for remediation issued by the MoE in 2000 and updated in 2002. This inventory is published in order to facilitate the decision-making process at different levels (national, regional, municipal). An updated list is currently under preparation.

**Fig. 2.5.1** Simplified Scheme of Procedures



- Directives of the NPF and the MoE for Preparation and Implementation of Projects concerning Past Environmental Damages in Privatized Property – a complex review of procedures to be followed during the process of hot spots assessment and remediation. The first Directive, No. 7/1998, was up-dated by Directive No. 1/2001 three years later and again by Directives No. 2/2003 and 3/2004. The directive is crucial for contaminated sites management and forms an obligatory annex to every contract with the NPF or the MoE. It explains the chronology of clean-up activities and includes specific procedures for each stage of the project cycle—Risk Assessment, Pre-remediation Survey, Feasibility Study and Remediation Project Design, Remediation and Supervision, and Post-remediation Monitoring. A strong emphasis is given to the requirements on public tenders, on obligatory reporting and on the decision-making process (including organisation of control days and responsibilities of all key stakeholders). Qualification criteria for implementing organisations (obligatory certificates and expertise, accreditations of analytic laboratories, relevant permits) or demands on budgeting and financing are also mentioned.

All these guidelines and registers reflect practical experience with land and water contamination assessment and remediation and are used as a code of practice by the CEI, the MoE and the NPF as well as by regional and local authorities. Although these guidelines are focused primarily on environmental problems linked to privatized state property, guidelines on expert assessment of environmental problems and on decision-making process can be applied in addressing other hot spots in the Czech Republic.

# 3. Examples of Methodological Frameworks

The review of methodology guidelines and directives in the previous section documents the complexity of the process and the need to unify and systematize the process for contaminated site management. From a procedural point of view, Directive 3/2004 of the NPF and the MoE is the most important. Two other methodologies on risk assessment and the database on past environmental damages are also significant from a professional point of view.

## 3.1 Risk Assessment

A report on Risk Assessment is a key document in the decision-making process—it forms the basis not only for the decision on whether or not remediation is necessary, but also for setting the target criteria and for selection of the best appropriate remediation method for the given site and for the given type of contamination.

The importance of this document was recognized in the very beginning of the remediation process in the Czech Republic and guidelines on Risk Assessment (published in 1996 by the MoE) were developed. Although there are still some reservations about the guidelines for developing the report and although the quality of individual reports varies according to the personal experience and responsibilities of project managers, the guidelines have become one of the most important documents influencing contaminated site management and risk control.

The experience gained in applying the guidelines demonstrated the need for some new requirements for the Risk Assessment report. Therefore, the MoE authorized an expert group to prepare a proposal of new guidelines and to discuss it with the general public before final publication at the end of 2004. A draft table of contents of the updated guidelines is as follows:

**INTRODUCTION**

**1. SITE SPECIFIC INFORMATION**

- 1.1 General information
  - 1.1.1 Geography (site location)
  - 1.1.2 Land use (including environment and landscape protection)
  - 1.1.3 Basic data on population in the given area
  - 1.1.4 Property ownership and other legal relations
- 1.2 Natural Conditions
  - 1.2.1 Geomorphology and climatic data
  - 1.2.2 Geology
  - 1.2.3 Hydrogeology
  - 1.2.4 Hydrology
  - 1.2.5 Geochemical data

**2. FIELD SURVEYS**

- 2.1 Existing information
  - 2.1.1 Results of previous survey or remediation works at the given site
  - 2.1.2 Review of contamination sources
  - 2.1.3 Probable contaminants and other risk factors
- 2.2 Current survey
  - 2.2.1 Methodology and scope of field survey and analytical works
  - 2.2.2 Results of current field survey
  - 2.2.3 Summary information on contamination extent and level
  - 2.2.4 Migration pathways
  - 2.2.5 Restrictions during data collection or processing, uncertainties

**3. RISK ASSESSMENT**

- 3.1 Hazards identification
  - 3.1.1 Specification of priority contaminants and other risk factors
  - 3.1.2 Characteristics of recipients
  - 3.1.3 Summary of migration pathways and exposure scenarios
- 3.2 Human risks assessment
  - 3.2.1 Dose - response relationship
  - 3.2.2 Exposure assessment
  - 3.2.3 Risk characterization
- 3.3 Environmental risks assessment
- 3.4 Summary of risks
- 3.5 Summary of uncertainties

**4. RECOMMENDATIONS FOR FOLLOW-UP**

- 4.1 Target criteria
- 4.2 Remediation options - scope, technology, time and costs estimation

4.3 Proposal of follow-up procedures

The new guidelines on Risk Assessment should also include a review of typical exposure scenarios with formulas for dose calculation and with typical coefficients and variables; links to national and international databases of dose-response data; relevant formulas, variables and invariables for risk quantification; links to other guidelines and manuals (e.g., field survey and remediation methods) and to other databases (e.g., database of past environmental damages, priority list of contaminated sites).

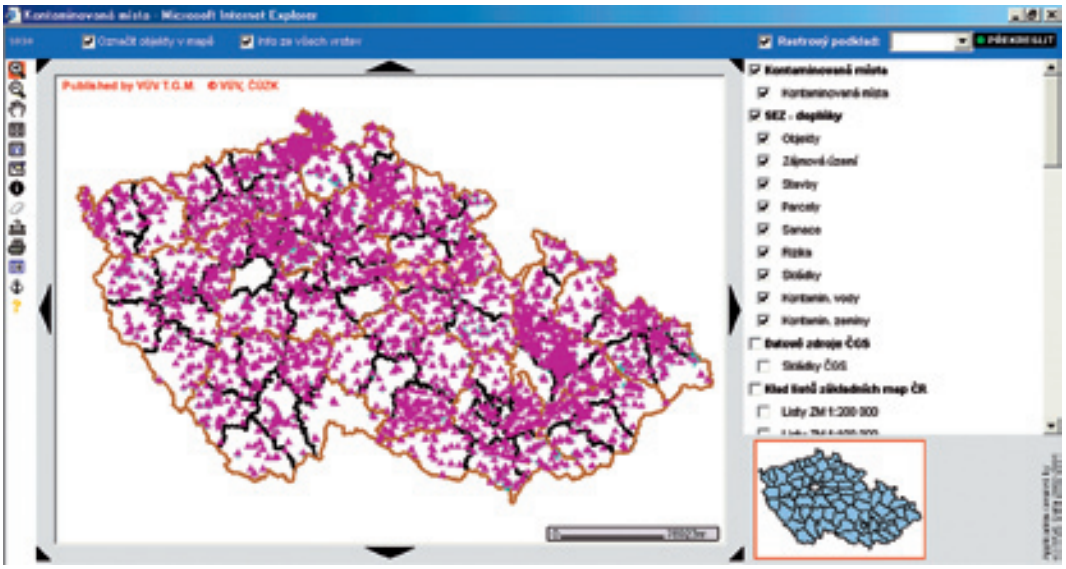
## 3.2 SESEZ—the Database of Past Environmental Damages

The information system of the Ministry of Environment is managed through the information gateway at the ministry Web site (http://www.env.cz) which centralizes all available data concerning hot spots in the Czech Republic. One of the main information sources is the Database of Past Environmental Damages, known as "SESEZ" (a Czech acronym for "contaminated sites evidence system").

The database was designed in 1996 and currently covers more than 7000 contaminated sites. There is information on 500 industrial and agriculture sites and former military bases (where remediation of past environmental damages is funded by the Ministry of Environment or by the National Property Fund), and on approximately 6500 landfills.

Basic data collecting software is built in Visual FoxPro and ArcView software, data storage is managed by ORACLE and ArcView. The copy of Web database is managed by ACCESS. The database consists of tabular and Geographic Information System (GIS) data.

**Fig. 3.2.1** Web presentation by MapServer - SESEZ sites in the Czech Republic

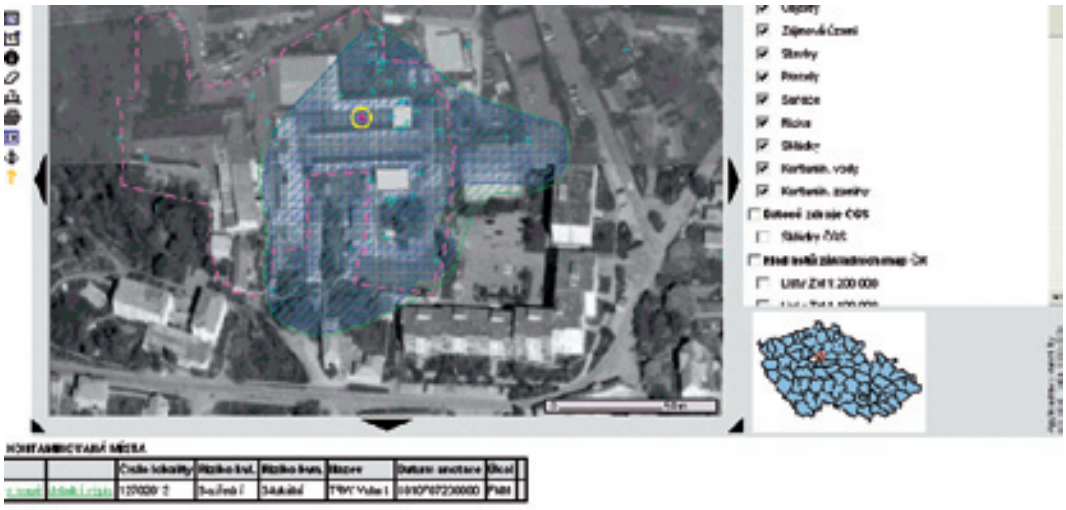


The SESEZ database is periodically updated and upgraded by the Water Research Institute of T. G. Masaryk (http://www.vuv.cz). The operational version of the database is accessible at: http://sez.vuv.cz.

The database includes information on geology, hydrology, geo-chemistry, property conditions, relevant decisions by municipalities and others, and information on remediation or survey companies working at a given site. The records include results of the Risk Assessment as well as results of other survey, monitoring or remediation works (results of chemical analyses of different media: soil, ground, surface and waste waters, soil-gas or building constructions).

Links to GIS offer complex information on each contaminated site. Sufficient choice of map scales and formats (including orthophotomaps) is provided in GIS and MapServer presentation and is user friendly.

**Fig. 3.2.2** TRW Volant in SESEZ - signal information (screen copy)



Data processing and update of the database SESEZ is conducted by:

1. Direct data inputing is carried out annually by The Water Research Institute of T.G.M.;
2. External data inputting is carried out on the basis of obligatory information from survey and remediation companies executing NPF or MoE funded contracts.

One of the important outputs of the database SESEZ is the ability to prioritize all contaminated sites by various criteria, e.g., by risks, by extent of contamination, by municipalities, etc. This year, the MoE decided to use this capacity to connect the SESEZ data with a (so far separate) "Priority List of Environmentally Damaged Sites".

The Priority List of Environmentally Damaged Sites still represents only approximate descriptive information on 833 sites. The list has been compiled in cooperation with regional authorities (MoE and CEI departments). According to the Czech Government Decision No. 51/2001, the priority ranking of the list should be an important factor in selecting sites for remediation. As the list also includes some abandoned sites or sites ineligible for NPF or MoE funding, it also provides important information for regional authorities.

The list was last updated in 2002. The full version is available at the MoE's Department of Environmental Damages Web site: http://www.env.cz/AIS/web.nsf/.

An update of the database SESEZ and of the Priority List with regard to the European criteria will be conducted during 2004 and 2005. The MoE will adjust both data collection and data processing criteria in order to be able, besides setting priorities for management of contaminated sites inside the Czech Republic, to correctly and easily report the required data to the European Environmental Agency (EEA).

**Fig. 3.2.3** Example of priority rating for the Priority list

| Locality | Site owner | Risks for public water sources | Risks for private water sources | Type of contam. | Contam. area | Migration | Priorities 2002 |
|---|---|---|---|---|---|---|---|
| Bzenec | KOVO | 3,50 | 2,50 | 2,00 | 1,50 | 0,50 | 10,00 |
| Rožnov pod Radhoštěm | TEROSIL (TESLA Sezam) | 3,50 | 2,50 | 2,00 | 1,35 | 0,50 | 9,85 |
| Lutín | Sigma Lutín | 3,50 | 2,50 | 2,00 | 1,35 | 0,45 | 9,80 |
| Benátky n. Jizerou | Carborundum | 3,50 | 2,50 | 2,00 | 1,50 | 0,25 | 9,75 |
| Pardubice - Semtín | ALIACHEM (+ DIAMO) | 3,50 | 2,25 | 2,00 | 1,50 | 0,50 | 9,75 |
| Sedlčany | Fesal + Pega Lift | 3,50 | 2,00 | 2,00 | 1,50 | 0,40 | 9,40 |
| Bor u Skutče | - | 3,50 | 2,50 | 1,60 | 1,35 | 0,45 | 9,40 |
| Mimoň | SAP | 3,50 | 2,50 | 1,80 | 1,20 | 0,20 | 9,20 |
| Nový Rychnov - skládka | (původně DUP Pelhřimov) | 3,50 | 2,50 | 1,60 | 1,20 | 0,40 | 9,20 |
| Ludslavice | STS - Pozemkový fond ČR | 3,15 | 2,50 | 2,00 | 1,20 | 0,25 | 9,10 |

# 4. Case Studies

## 4.1 Remediation of TCE Contamination in a Fractured Aquifer System Using Steam Enhanced Extraction

Groundwater contamination by hydrocarbons[2] was detected at the site of a manufacturer of automobile parts in Prague during an ecological audit in 1992. Consequently, in 1995 the NPF and the manufacturer signed an Environmental Liability Agreement on remittance of remediation costs. A very high level of contamination was confirmed in the risk assessment in 1996 and in further surveys in 1998. Based on these findings, a tender on remediation was announced. After appraisal of all project proposals, the use of a pilot application of a special remediation method called "Steam Enhanced Extraction" (SEE) was selected (licensed by Prof. Udell of the University of California, Berkley). The remediation was launched in 1999 and an independent company was authorized to supervise the remediation process.

Geologically, the site is made up of horizontally layered sedimentary rocks with alternating mid or fine-grained sandstones, siltstones and clay-stones. During the geological survey, open vertical fractures of up to 3 cm in sandstone rocks were found. Two perpendicular systems of fractures separate 3 to 5 m blocks of hard sandstone. All observed fractures ended in pliable clay-stones and siltstones. The site contained four above-laying aquifers of permeable rock (sand and sandstones), separated by less permeable clay-stones and siltstones. Some open fractures located in more permeable zones (with groundwater flow) were observed as well.

The contamination was composed of a mixture of more than 10 Dense Non-Aqueous Phase Liquids (DNAPL) compounds. The physical and chemical properties of DNAPL (i.e., low solubility, and more dense and less viscous than water) make them particularly mobile in an aqueous environment but very difficult to extract. When DNAPL presence is combined with soil heterogeneity, the application of classical remediation technologies (for example, pump and treat technology, soil vapor extraction) practically excluded the possibility of reaching the acceptable remediation parameters within reasonable timeframes. The DNAPL contamination at the site was present in the upper two aquifers, but was mostly concentrated at the center of the site (isolated DNAPL accumulations retarded by the clay stone). Initial concentrations of total CHCs in groundwater exceeded 80 $mg.l^{-1}$.

The SEE remediation consisted of four different phases: 1) contaminated area dewatering to facilitate the steam injection and vapor extraction; 2) continuous steam/air injection to heat the contaminated zone as fast as possible in order to the maximum temperature; 3) pulsed steam/air injection and vapor extraction to clean less permeable zones enhanced by high hydraulic gradients; and 4) clean water injection combined with pump and treat technology to complete groundwater remediation and to reach fixed remediation limits.

The first and partially the second aquifers were dried during remediation activities. As a result, the groundwater level was measured (during SEE technology application) at depths of 7 m under the surface while at the beginning of operation only at depths 5 to 5.5 m under the surface.

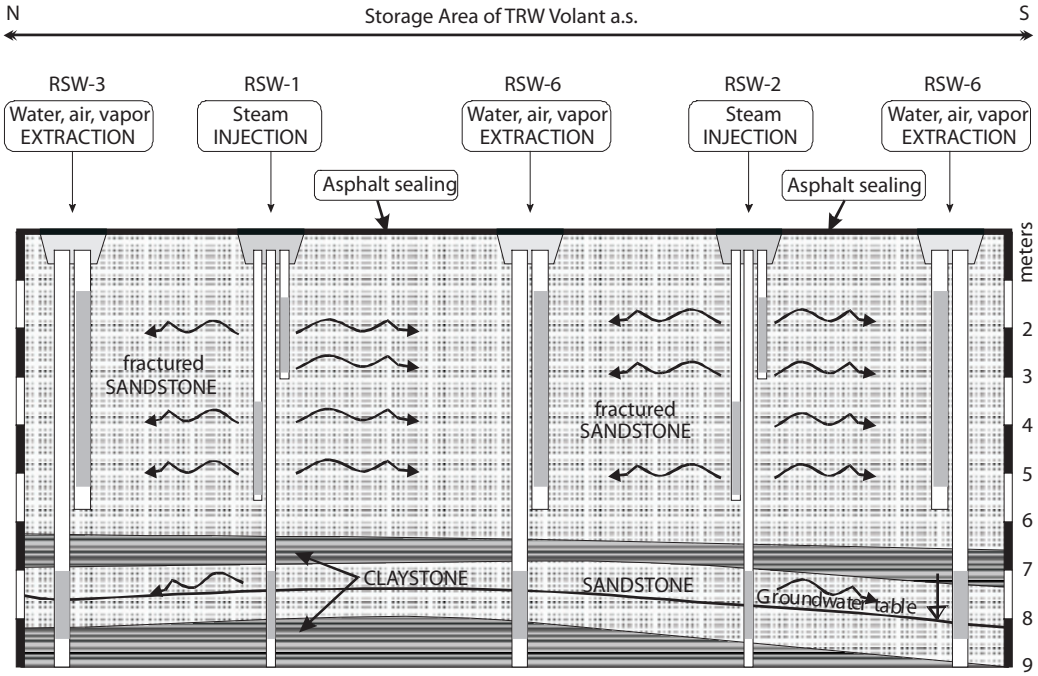
The steam and air were first continuously co-injected into two wells while vapors were extracted from a series of seven vapor and water extraction wells in the surroundings. The steam was injected into three different horizons (at a rate of 250 $kg.h^{-1}$); the vapor was extracted from two different horizons by means of four vacuum pumps with a total capacity of 600 $m^3.h^{-1}$ (see figure 4.1.1).

Injection and extraction intervals covered the entire contaminated area, but the water and vapor transmission between two aquifers was prevented by the bentonite and cement well packing. Due to numerous operational restrictions and to limited access to heavily used areas of the factory, the water/gas treatment station had to be situated off the site and all pipes and cables had to be installed under the surface.

Approximately four weeks were needed to heat the contaminated soil to the maximum temperature (100°C); for more than four subsequent months the temperatures remained high. After the aquifer system was heated to the maximum temperature, the cyclical regime of air-steam injection took place. The objective of cyclic operation was to remove TCE from a less permeable block separated by more permeable zones or fractures.

[2] Chlorinated hydrocarbons (CHCs), predominantly trichloroethylene (TCE).

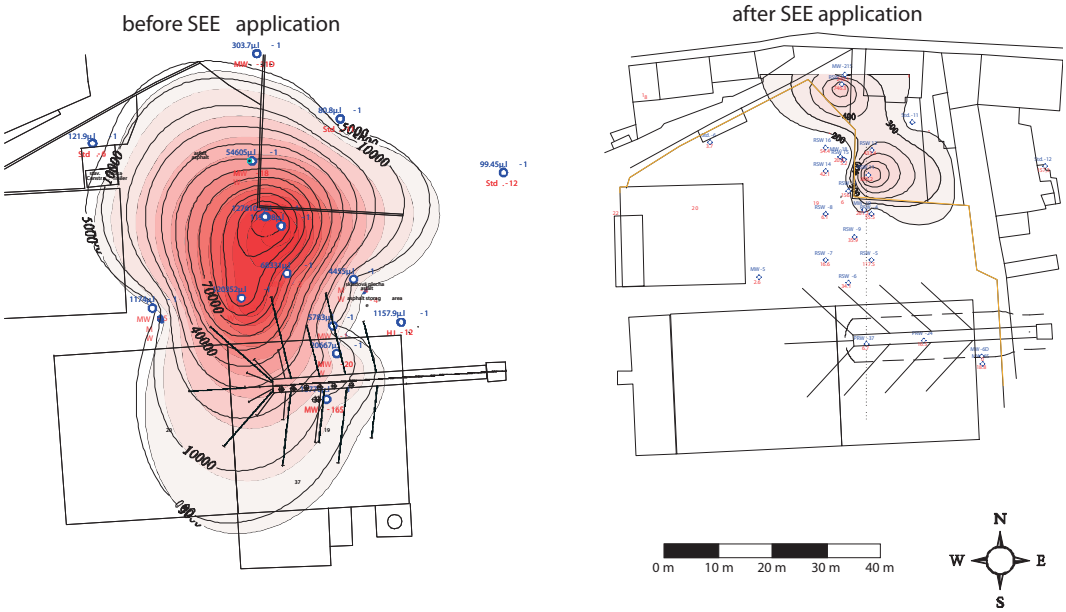
**Fig. 4.1.1** Vertical geological profile and SEE system configuration.




The monitoring system allowed the observations of time and spatial evolution of temperatures and contamination concentrations in water and soil gas. Measurement of pressure and gas flow rates, combined with numerical modeling, allowed for optimization of the extraction system efficiency. All parameters allowed control of the remediation progress and the prevention of undesired DNAPL dispersion out of the primary contaminated zone. Temperatures were collected twice a day by means of 100 resistive thermocouples placed at six different depth intervals around the heated zone. Water and gas samples were regularly collected and analyzed as well.

During the SEE application, the major part of contamination was extracted in the vapor phase. Total CHC concentrations in extracted gas increased more than 200 times. At the same time, a rapid decrease in groundwater contamination was observed. Total CHC concentrations in the groundwater decreased 1000 times during one month of SEE application and 3.8 tons of pure TCE product were removed by the end of remediation. The remediation success is documented on Figure 4.1.2 below, where the initial and final contamination distribution is compared.

**Fig. 4.1.2** Comparison of initial and final contamination distribution



Steam Enhanced Extraction technology (SEE) is an innovative and very efficient remediation technology. Results have demonstrated that this technology can remove large amounts of contaminant mass and reach desired clean-up levels in a very short time. The required targets were reached in 2001 and remediation was finished in 2002. The site will be monitored until the year 2007.

The total approved budget for remediation and monitoring at the site was about 1.08 million USD.

## 4.2 Bioremediation of Groundwater and Soil Contamination

An extremely high level of petroleum hydrocarbons[3] contamination was found both in sand and gravel sediments and in groundwater at the site of a chemical factory of a leading Czech producer of industrial fertilizers. The site is situated 60 km northwest of Prague, on the banks of the Labe River. The extent and corresponding level of contamination was confirmed by further field surveys and by a risk assessment that established the need to start a clean-up process. The initial levels of contamination, as well as the target limits, are summarized in the following table.

**Table 1** Level of pollution / target limits

| Content of contaminants (TPH) | Average | Maximum | Target limit |
|---|---|---|---|
| soil (mg/kg) | 75 000 | 390 000 | 3 000 |
| groundwater (mg/l) | phase | phase | 3 |
| soil gas (mg/m$^3$) | 1 200 | 8 400 | 450 |

After a public tender, a project design was approved in 1998 that combined the following remedial methods:

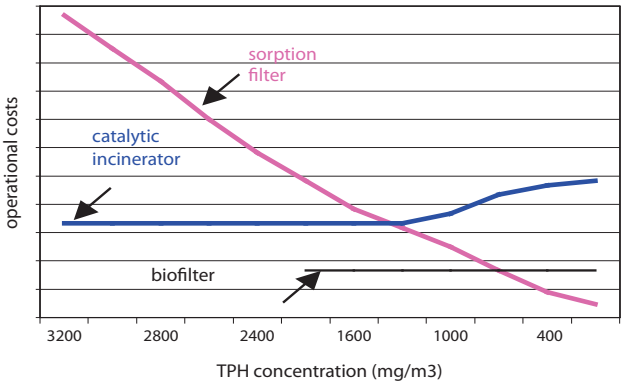
***Groundwater pump & treat***

- groundwater extraction from wide-profile remedial wells (04/2001 - 05/2003) with separate groundwater pumping and extraction of petroleum from the water table (see firure 4.2.1 below), gravity separation of petroleum and its incineration off site
- in-situ bioremediation (07/2002 - 07/2003)

**Soil remediation**

- excavation and subsequent "ex situ" bioremediation (05/1999 - 03/2000)
- soil vapor extraction from horizontal wells (03/2000 - 10/2001) with treatment of extracted soil gas in catalytic incinerator, absorbers and bioreactors
- "in situ" soil washing / bioremediation (01/2002 - 07/2003)

**Fig. 4.2.1** Comparison of operational costs related to various methods of extracted soil gas treatment (depending on TPH concentration in extracted soil gas)




Bioremediation was the core principle of the clean-up process. Bioremediation is one of the most frequently used methods in the Czech Republic both for groundwater remediation and for soil remediation in situ and off site. Bioremediation is based on the ability of certain bacterial strains to utilize petroleum hydrocarbons (TPH) as a source of carbon and energy for their growth: organic contaminants are decomposed by an aerobic biochemical processes to non-toxic final products of carbon dioxide and water. TPH are non-polar substances insoluble or only partially soluble in water. The applied bacterial strains produce surface-active substances (surfactants) that, due to the amphipathic properties of their molecules, disturb the boundary layer between the hydrophobic crude-oil film and the polar aqueous medium. This enables even ordinary soil bacteria to come into contact with the surface of hydrocarbon molecules and to involve them in the process of decomposition. To accelerate the decontamination process, it is useful to create ideal conditions for bacteria growth by establishing the appropriate soil humidity, concentration of oxygen and nutrients in the treated soil, and temperature.

The remedial works at the site were interrupted in August 2002 because of floods but were completed in May 2003. The post-remediation monitoring and final verification sampling in December 2003 confirmed that target limits were met with current average levels of TPH in soil, soil gases and groundwater of 700 mg/kg, 200 mg/m$^3$ and 0.5 mg/l, respectively.

During remediation, 6200 tons of contaminated soil were excavated and biologically treated (with approx. 465 tons of petroleum compounds), 230 tons of petroleum compounds were extracted from groundwater and 10 tons of petroleum compounds were extracted from soil gas.

The total project cost was 1.35 million USD. The average cost for extraction of 1 kg of pure contaminant from soil and groundwater was approximately 1.9 USD.

[3] Total petroleum hydrocarbons (TPH).

# Appendix I. The Czech Legal Framework

**Privatization.** The basic legislative documents concerning past environmental damages are: Act No. 92/1991 Coll., on the conditions for the transfer of the state property to other subjects, as amended in Act No. 92/1992, as amended; Act No. 171/1991 Coll., on affairs concerning transfer of state property to other subjects and on the National Property Fund, as amended; and Government Resolutions No. 379/1992, No. 455/1992, No. 694/1992, No. 123/1993, No. 568/1993, No. 393/1994, No. 178/1995, No. 20/1997, No. 212/1997, No. 810/1997, No. 917/1999, No. 51/2001.

Government Resolutions No. 455/1992 and No. 123/1993 started a systematic approach in remediation of old environmental damages. Further Resolutions, especially No. 810/1997 and the latest, No. 51/2001, have laid down new details concerning the remediation process.

Government resolution No. 51/2001 deals with privatization projects submitted on or before February 29, 1992, i.e., those without an ecological audit. In such cases, a new owner may submit a request to the Government on concluding an agreement even after a decision on privatization. The agreement can be concluded only in the case of serious environmental damage that demonstrably occurred prior to privatization, especially at sites with endangered mass-supply drinking water sources.

All public contracts for any stage of remediation process must be implemented pursuant to Act No. 199/1994 Coll., on tenders for public contracts, as recently amended by Act No. 40/2004. The requests for proposals are announced by the NPF. Further details are laid down in Directive No. 3/2004 of the NPF and the MoE for Preparation and Implementation of Projects concerning Past Environmental Damages in Privatized Companies.

Between 1991 and 2003, there were 269 Environmental Liability Agreements concluded up to the amount of 5382 million USD (currently reduced to 5158 million USD); payments were made in the amount of 673 million USD. The agreements were already terminated at 61 sites (23 %).

**Former Soviet Army Sites.** The presence of the former Soviet Army in the Czech Republic territory lasted 23 years and led to significant environmental damages. The last train with Soviet soldiers and military equipment left the Czech Republic in June 1991. In September 1991 the Czech-Slovak Federative Republic Government, through Resolution No. 577/1991, established the "Authority for dealing with the consequences of the stay of the Soviet Army". In the same year, however, this Authority accepted no claims and obligations, which meant the loss of any financial compensation from the Soviet side. In November 1992, this authority was abolished in connection with the abolishment of the Czech-Slovak Federative Republic; the agenda as well as the competence for remediation of these sites was transferred to the MoE by Government Resolution No. 2/1993. Between 1990 and 2003, the total expenditures for remediation work at former Soviet Army sites, including risk assessment and monitoring, was approximately 44.6 million USD. It is expected that an additional 9.3 million USD will be necessary until the year 2011.

**Water Act.** Section 40-42 of the Water Act No. 254/2001 Coll., as amended, came into force in January 2002 and provides that the "water protection authority" should open a special account which would be annually complemented up to sum of 1.9 million USD for emergency cases of endangered surface water or groundwater. In specific cases, the fund would also cover remediation of historical contamination. By the end 2002, water protection authority was devolved to 78 Districts. Thus, there should have been an available sum of almost 146 million USD, but this theoretical fund was used only in a sporadic way because practically no financial reserve was in fact available in the State Budget.

On the basis of the amended Water Act that came into force in 2003, the sum of 1.9 million USD was transferred to the MoE, and the mechanism for using this fund was the same as in cases of contamination caused by the former Soviet army. In 2003, remediation works (including supervision) were running at three sites, post-monitoring at one site, and risk assessment at 12 sites.

According to the latest version of the Water Act (Act No. 20/2004 Coll.), regional water protection authorities were newly established at 14 Regional Districts and a special account for the above purposes is to be opened with an annual sum of 374 thousand USD for each Regional District.

**Other cases.** In addition to the above remediation options, an ad hoc Government resolution can be prepared for a specific case or region. It is mostly used for remediation of brownfields in order to support new investments in socially endangered regions. Typical examples can involve revitalization of former coal or uranium mining areas in Northern Moravia or Northern and Central Bohemia.

The State guaranties for brownfields were approved up to the sum of 1346 million USD.

1 USD = 26.754 CZK (Czech National Bank, 20 May 2004).

# Appendix II. Acronyms and Abbreviations

| | |
|---|---|
| CEI | Czech Environmental Inspection |
| E.I.A. | Environmental Impact Assessment |
| EC | European Commission |
| EEA | European Environment Agency |
| LF | Land Fund of the Czech Republic |
| MoE | Ministry of the Environment of the Czech Republic |
| NPF | National Property Fund of the Czech Republic |
| ODA | Official Development Assistance |
| SEE | Steam Enhanced Extraction |
| SESEZ | Contaminated sites evidence system (Database of Past Environmental Damages) |
| TOR | Terms of Reference |
| UNDP | United Nations Development Program |
| UNEP | United Nations Environmental Program |
| UNICEF | United Nations Children's Fund |
| UNIDO | United Nations Industrial Development Organization |

# Appendix III. References

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http://www.env.cz (Ministry of Environment)

http://www.fnm.cz (National Property Fund)

http://www.vuv.cz (Water Research Institute of T. G. Masaryk)

http://sez.vuv.cz (SESEZ database)

# United Nations Development Programme (UNDP) Eastern Europe and Commonwealth of Independent States (CIS)

## Bratislava Regional Centre

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