German Policies on Soil Protection and Remediation of Contaminated Sites

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Summary

Germany as a densely populated and heavily industrialised country has a long and broad experience in handling contaminated sites. With this presentation we want to describe some main aspects of the soil protection policies and the remediation of contaminated sites in Germany. Due to the history of working on contaminated sites in Germany the Federal Soil Protection Act came into force in 1998. A lot of programmes and network in Germany and in Europe, funded by the State or the European Union, helped developing new measures and techniques for remediation and also for implementing regulations for the involved authorities. Questions like "who is responsible?" and "who has to pay for measurements and the remediation?" became more and more important. In the near future there will be an official European Soil Protection Policy (is expected in June 2004). Besides the contaminated sites also other soil protection policies as "Reducing the land consumption" are pursued and an indicator is developed.

Introduction

Looking back at a history of more than 150 years of industrial development and military activities and an even older history of mining in Germany, the often shortsighted environmental policies left numerous contaminated sites as inheritances from the past. However, only since the early 1970s, when spectacular cases of polluted soil and contaminated groundwater as a potential hazard for the population and the environment attracted public interest in Germany, have an environmental awareness and requests for environmental protection emerged. In

1978, the first estimation of suspected contaminated sites comprised 50,000 catalogued sites, rising to more than 362,000 sites in 2000. The sharp rise in the number after German Reunification is primarily attributed to the serious environmental problems in the New States. However, the suspicion of contamination has not been confirmed at all sites, and as a rule of thumb only 10–15 % of sites need actual remediation. In recent years, considerable efforts have been made to clean up and redevelop contaminated sites, mainly aimed at restoring and subsequently protecting soil or groundwater and thus averting potential hazards.

However, remediation is also carried out to eliminate the inhibiting effect of abandoned sites as an economic obstacle to further investment, privatisation and competition. The general tendency is towards the redevelopment and recycling of Brownfield Sites instead of the development of Greenfield sites for the settlement of commerce, industry or housing. Following the strategy for sustainable development, the German government intends to reduce land consumption from the current 1.3 km^2/d to 0.3 km^2/d in 2020. The constant increase of land use for settlement and traffic area, however, has several adverse effects. Land consumption may account for the loss of sensitive biotopes for flora and fauna, for the degradation of soils as well as for the loss of biodiversity as a result of interfering and diminishing natural habitats. In addition, groundwater may be less protected against contamination and its regeneration may be inhibited by lower precipitation seepage. The increasing sealing of soils has resulted in large amounts of run-off rainwater, which has to be drained via channels and rivers. Local and regional climate is also adversely affected by land use for settlements and traffic. Last but not least the increasing expansion of areas used for traffic networks is promoting the development of more traffic.

1. Soil contamination

The introduction of contaminants in the soil may result in damage to or loss of functions of soils and possible cross contamination of water. The occurrence of contaminants in soils above certain levels entails multiple negative consequences for the food chain and thus for human health. A distinction often is made between soil contamination originating from clearly confined sources (local or point source contamination) and that caused by diffuse sources.

1.1 Local soil contamination

Local (or point source) contamination is generally associated with mining, industrial facilities, waste landfills and other facilities both in operation and after closure. Although the largest and most affected areas are concentrated around the heavily industrialised regions in Northwest Europe, contaminated sites exist everywhere throughout the continent. Wasteland filling is another potentially contaminating activity of major relevance: on average, 65% of municipal waste generated in the EU (190 million tonnes in 1995) is still land filled. In waste landfills leaching can be emitted to the surrounding soil and soil parent material and subsequently enter groundwater and/or surface water. Of particular concern are those that operate or have operated in the past, without complying with the minimum set of technical requirements set by the Landfill Directive.

Estimates of the number of contaminated sites in the EU range from 300 000 to 1.5 million. This wide range in estimations is due to the lack of a common definition for contaminated sites and relates to different approaches to acceptable risk levels, protection targets and exposure parameters. Soil clean up is a difficult operation with very high costs. Expenditure for de-contamination of contaminated sites greatly varies between Member States. In 2000 the Netherlands invested EUR 550 m in decontamination, Austria 67 and Spain 13. Such disparities reflect different perceptions of the severity of the contamination, different remediation policies and targets, and different ways of estimating expenditure. The European Environment Agency has estimated the total costs for the clean up of contaminated sites in Europe to be between EUR 59 and 109 billion. Knowledge sharing and targets for clean up are important paths to resolving contamination issues today, but prevention of further contamination needs to be the future objective.

1.2 Diffuse soil contamination

Ammonia and other nitrogen deposition (resulting from emissions from agriculture, traffic and industry) cause the unwanted enrichment of soils. A number of farming practices can also be considered as a source of diffuse soil contamination. An additional problem relates to heavy metals (e.g. cadmium, copper) in fertilisers and animal feed. Their effects on soil and soil organisms are not clear, although studies have shown the possible uptake of cadmium in the food chain. The effects on soil of antibiotics contained in animal feed are unknown. Pesticides are toxic compounds

deliberately released into the environment to fight plant pests and diseases. They can accumulate in the soil, leach to the groundwater and evaporate into the air from which further deposition onto soil can take place. The volume of pesticide active ingredients sold across the 15 European Union Member States reached 321,386 tonnes in 1998. The only apply should follow Good Farming Practice. The cost of diffuse soil contamination is not seen so much in soil itself, but in the consequences of the breakdown of the buffering capacity of soil. Although the precise cost has not been counted so far, the clean up of organic compounds, pesticides, plant nutrients and heavy metals from water is known to be very costly.

2. Management of contaminated sites

2.1 Legal framework

The management of contaminated land and groundwater demanded a federal law. In 1999, the Federal Government in Germany put the Federal Soil Protection Act into force, which established nationally standardised regulations for the registration and remediation of contaminated sites and which replaced the former, often contradictory, regulations of the various States. Since then, the individual States represent the Soil Protection Authorities, being responsible for the enforcement of the Federal Soil Protection Act.
The most important objective of the Act is to protect the soil against harmful impacts on its functions, to prevent soil contamination and to regulate the clean up of abandoned contaminated sites. According to the Federal Soil Protection Act, harmful impacts on soil functions are defined as hazards implicating considerable disadvantages or nuisances for individuals or the general public.

Contaminated sites are shutdown waste recycling and disposal facilities (old deposits) and sites of shutdown facilities and areas where environmentally hazardous substances have been used (abandoned industrial sites). On contaminated sites, known changes in the soil or other hazards for individuals or the general public exist.

Suspected contaminated sites are properties where there are concrete grounds for suspecting that harmful changes in the soil or other hazards for individuals or the general public exist. Locations, which were formerly used by the military or for armament production, are also classified as suspected contaminated sites.

The Federal Soil Protection and Contaminated Sites Ordinance of 1999 specifies the criteria for the risk assessment. It introduces threshold values for the content of toxic substances in the soil. These values are the basis for identifying and assessing the need for remediation.
In agreement with the **polluter pays principle**, the person who caused the contamination is held responsible. Beyond the polluter, the owner or occupier is also responsible. If the site owner was not the polluter and was also not aware of the pollution when buying the site, the Act limits the liability: in this case the owner has to bear remediation costs only up to the maximum market value of the site.

Relevance of trigger, action and precautionary values:

If the trigger value is exceeded, further investigations are required to determine whether a harmful soil change or site contamination exists. The need for investigations takes into account the future use of the soil in playgrounds, residential areas, parks and recreational facilities, industrial and commercial properties or agricultural areas and pathways, and possible contacts such as soil–human being (direct contact) or soil–food plant.

The exceeding of the limit for the action value of a hazardous substance normally signals the presence of a harmful soil change or site contamination and means that appropriate measures are required.
Precautionary values are soil values, which, if exceeded, normally indicate that concern for a harmful soil change exists.

3. Programmes and Networks

A lot of programmes, funded by the State or the European Union, helped to develop techniques and caused networking and led to international partnership on remediation of Contaminates Sites.

A good example for an effective international cooperation is the **NATO/CCMS-Pilot study about innovative remediation techniques**, done during three steps in the NATO-Committee Programme on the Challenges of Modern Society (CCMS), started in 1986, managed by the USA, the Netherlands and Germany. It was finished in 2002 and more than 20 countries worked together successfully.

From 1993 to 2000 a German research network "**Bioremediation of Contaminated Soils**" took place (costs: 17,5 Mio Euro) and one of many results was a Guideline for Bioremediation (Dechema e.V.) that is unique internationally.

CARACAS (Concerted action initiative on risk assessment for contaminated sites), 1996 – 1998, was funded by the European Commission under the Environment and Climate Programme and co-ordinated by the Federal Environmental Agency (Umweltbundesamt). More than 50 scientists and policy specialists from 16 European countries had carried out the work programme.

SAFIRA (Remediation Research in regional contaminated aquifers), from 1999 ongoing, is a research network on groundwater treatment in cases with a complex hazardous substance inventory. Development and testing of new reactive materials in semi technical scales followed on Bitterfeld site (costs: 12 Mio Euro) in cooperation with a Netherland Research Institute (TNO), one of the pilot projects for the NATO/CCMS Study, which got great international interest.

CLARINET (Contaminated Land Rehabilitation Network for Environmental Technologies), 1998 – 2001, was a concerted action. The main question was how to reduce the cost of dealing with land contamination without compromising public health and water quality.

RUBIN (PRB – Permeable Reactive Barriers), 2000 – 2003, is a German research network with 10 projects and the objective to get a guideline for the use of PRB during groundwater remediation and a manual with examples to prepare, build and work with PRBs.

Some examples for concrete remediation projects in Germany are mentioned in the appendix.

4. European Soil Protection Policy

One of the objectives of the Sixth Environmental Action Programme of the European Union is to protect soils against erosion and pollution. It shall pave the way for

developing a strategy on soil protection. The main threats to soil in Europe are identified as:

- erosion
- decline in organic matter
- soil contamination
- soil sealing (caused by the covering of soil for housing, roads and other infrastructure)
- soil compaction (caused by mechanical pressure through the use of heavy machinery, overgrazing or sporting activities)
- decline in soil biodiversity
- salinisation (excessive accumulation of soluble salts of sodium, magnesium and calcium) and floods and landslides.

All these processes are either driven or exacerbated by human activity and some degradation processes have increased over recent decades. The economic consequences and restoration costs linked to the threats to soil are huge.

As regards Community initiatives as such, the Communication stresses that an explicit Community policy does not exist at this stage. However, measures implemented under other policies (environmental, agricultural, regional, transport, research) contribute to soil protection. It is therefore essential that the EU develop a Community thematic strategy for soil. This strategy will be presented in 2004. It will take into consideration the principles of precaution, anticipation and environmental responsibility, and will focus on initiatives already being undertaken in environmental policies, better integration of soil protection in other policies, soil monitoring and new actions based on monitoring results.

In environmental policy, new legislation will supplement existing legislation:

- in 2002: 4th Daughter Directive on air quality and a directive on mining waste
- in 2003: revision of the Sewage Sludge Directive and Communication on Planning and Environment, focusing on sustainable use of soil
- by the end of 2004: directive on compost and other bio waste

The Common Agricultural Policy (CAP) will encourage organic farming, the maintenance of terraces, safer pesticide use, use of certified compost, forestry, forestation and other measures for soil protection. Under the review of the CAP, the

European Commission intends to expand the financial commitment to rural development and soil protection. As regards soil monitoring, the Commission will propose, by June 2004, legislation on a Community information and monitoring system for soil threats. This monitoring will provide the basis for future legislative initiatives and will be used as a tool to adjust and review existing policies in the field of soil protection.

5. Reducing the Land Consumption

An indicator represents the growth of land use for settlements and traffic in Germany measured in hectares (ha) per day. As an environmental objective the restriction of land use for settlements and traffic shall decrease to 30 ha/day by 2020.

In 2001, the land used for settlement and traffic accounted for 12.3 % (43,940 km²) of the total surface area in Germany, consisting of:

- 52.5 % or 23,081 km²; for edificial and undeveloped areas, including about
  - 24 % for residential areas and
  - 28 % for non-residential use
- 39 % or 17,118 km² for traffic areas
- 6.9 % or 3,009 km² for recreational areas including cemeteries and
- 1.7 % or 732 km² for industrial areas (e.g. for stocking, dumping, purification plants and similar open air activities excluding mining land)

Approximately half of the land used for settlement and traffic consists of sealed surfaces, which has a substantial effect on soil functions.

Over the last three years, there has been a constant increase of land used for settlements and traffic of about 131 hectares (ha) per day, which indicates an increase of nearly 10 % compared to 1997, the base year of the indicator. The annual increase of 478 km² currently corresponds to an area of approximately 1.5 times the size of the city of Munich. Figure 2 illustrates the degree to which actual progress in land consumption corresponds to the annual reduction necessary to achieve the environmental objective. It demonstrates clearly that the objective cannot be achieved if land development continues its recent trends.

It will be essential, however, to make the reuse of land a top priority over the allotment of new settlement areas in order to initiate a trend reversal.

Various measures need to be set on in order to comply with the environmental objective, including conservative use of land in construction, reuse of land (i.e. reuse of contaminated
sites) and unsealing of soils. In addition, the evaluation of soil function must be taken into greater consideration during the planning of construction in order to improve land management (e.g. stricter requirements for use of particularly valuable land, more construction on land which is already sealed). Moreover, the allocation of different land uses needs to be optimised, e.g. the proximity of workplace and home. Furthermore, the aggregation of existing areas of settlement should be promoted by the means of incentives instead of allowing further construction on unsealed land.

References and further Information

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Further Information

EUGRIS (European Information System Soil and Groundwater) is a new European online information system for questions about Contaminated Soils and Groundwater. Partners from Denmark, France, United Kingdom, Hungary, Italy and Germany are involved. It will work out the state of the Know how and shall spread the information about the national research programmes on remediation. It is co-ordinated by the Federal Environmental Agency (Umweltbundesamt). http://www.eugris.org

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Appendix Remediation examples

A 1 Abandoned industrial sites

The size of abandoned industrial sites ranges from shut-down industrial complexes, e.g. factories for steel or chemical production, to former small family businesses on the corner, e.g. dry cleaners or service stations. Hazards emanating from abandoned industrial sites can be of various types, all involving impacts on soil, water or air caused by the former industrial use. Depending on the former industrial area and thus the handling of particular environmentally hazardous substances, the quantities involved and the duration of processing at the site, an inventory of typical pollutants and their characteristics might be evaluated. Usually the so-called expected contamination profiles in addition to manufacturing files are very helpful for historical investigations because they give indications as to whether, for example, tanks and their inlets, sewers, filling stations, tar pits, etc. exist or which harmful substances might be expected. When the existence and location of those potential contamination sources cannot be reconstructed, considerably more

complex and expensive investigations are needed in order to clarify the circumstances.

Table. Examples of industrial sectors and their typically harmful substances

Industrial sector	Harmful substances
Electro- Engineering, metal machining, plating	(Volatile) halogenated hydrocarbons
Paint and varnish production	Arsenic, copper
Glass and mirror manufacturing	Lead, arsenic, mercury, tin
Wood impregnation, cyanizing	Mercury, chromium
Leather manufacturing	Chromium, (volatile) halogenated hydrocarbons
Scrap yards	Lead, petroleum-derived hydrocarbons
Filling stations, petrol stations	Petroleum-derived hydrocarbon
Gasworks	Polycyclic aromatic hydrocarbons, aromatics
Tar converting	Polycyclic aromatic hydrocarbons

The extent of the environmental impact depends on the type and concentration of the hazardous substances and also on the exposure of the protected object, e.g. soil, air or groundwater. Groundwater damage, for example, is often caused by contaminated seepage water whereas environmental impact on surface water is mainly caused by direct discharge of contaminants in the water.

A 1.1 Remediation of a former metal processing enterprise in Attendorf (North Rhine-Westphalia)

More than 100 years of metal processing in Attendorf led to contamination of the buildings, soil and groundwater at the site. The main sources of contamination were petroleum-derived hydrocarbons, polychlorinated aromatic hydrocarbons, polychlorinated biphenyls and heavy metals. The aim of the remediation was to guarantee the multifunctional usability of the site for subsequent development as a residential and commercial area.

At the time of its closure in 2000, the enterprise comprised a building stock of approximately 70,000 m^3, including processing floors, office buildings and residential houses. Before the deconstruction of the buildings could be carried out, 4,000 tons of polluted material from the walls and floors were removed and

separately disposed of. Some 9,000 tons of uncontaminated material from the buildings were recycled and reintegrated at the site, and 6,000 m^3 of soil were excavated and the uncontaminated components reintegrated. The remediation was completed in December 2001.

A 2 Disposal of old waste

With a lack of awareness of how dumping waste might affect public health and the environment, depositing waste in unsecured landfills or heaps has been a well-established practice for a long time, particularly in the former GDR (German Democratic Republic). Based on the then major assumption that the natural underground is impermeable, no additional technical measures were taken to seal the base and the sides of waste disposal sites.
Even in 1995 only 60 % of the German disposal sites possessed a base seal, whereby the implementation of sealings are to be found more frequently in the Old States than in the New States, as seen in the following Table:

Table: Sealing of the base of disposal sites in Germany in 1995 (source: Federal Environmental Agency, 1997)

	Completely existing	Partly existing	None
Old States	115	123	32
New States	12	26	164
Germany (total)	127	149	196

In the course of the further development of industrial production techniques and the growing mentality of the "throw-away society", the amount of waste has increased drastically in recent decades. In addition, industrial waste, in particular from chemical plants, became noticeably more pollutant. Especially the decaying manufacturing facilities and the outdated technologies used in the territories of the former GDR had produced large amounts of hazardous industrial waste. The problems of waste and its disposal are aggravated by the fact that waste of unknown composition and in unknown volumes was dumped as landfill in abandoned mining pits.

A 2.1 Legal framework

For the operation and closedown of current disposal sites, European Directives exist which have been put into national legislation in Germany by several technical instructions and Ordinances. The so-called old disposals that were shut down prior to 1972 in the Old States and prior to 1990 in the New States and the remediation of those sites are subject to the Federal Soil Protection Act.

The operation and closedown of disposal sites in Germany are controlled by the provisions of the **Disposal Site Ordinance** (2002), the **Waste-Disposal Ordinance** (2001), and also the **Technical Instruction on Municipal Waste** (1993) and the **Technical Instruction on Waste** (1991). The latter instruction is of particular importance for waste requiring special supervision. Waste dumped in former underground mining pits is subject to the **Ordinance on Underground Waste Storage** of 2002.

To deal with the potential hazard of groundwater contamination by disposal sites, a First General Waste Administrative Regulation over Requirements for the Protection of the Groundwater with the Storage and Deposit of Wastes was released in 1990.

A 2.2 Typical contaminations

The hazardous potential emanating from abandoned disposals depends on the type and amount of dumped materials. Whereas abandoned industrial sites in general have a specific inventory of hazardous substances, such an inventory does not exist for disposal sites. Instead, often waste of unknown source and indefinite composition is found. In general, waste is classified as municipal waste, building site waste, soil excavation and hazardous waste.

As a result of leachate flowing through unsecured dumps, hazardous impacts on soil and particularly on groundwater occur. Therefore, remediation of old disposals involves technical measures not only to effect a clean-up but also to prevent further contamination by the application of safety regulations on waste sites.

The remediation and securing of old disposals focus mainly on the implementation of surface sealing of landfill bodies to prevent the further inflow of leachate. Another focus is set on the sealing of the sides of landfill bodies to prevent groundwater from flowing into it and leachate from leaking. The subsequent sealing of the base of old deposits or the base of deposits in former mining pits has never been carried out because of the enormous costs and technically intricacy.

In practice, the implementation of appropriate measures comprises techniques such as:

- covering the landfill body with a soil layer several metres thick
- sealing with an almost impermeable mineral cover sheet
- sealing with overlapping, welded or bonded plastic foil which can be covered with a soil layer or pinned down by tyres or sandbags
- sealing with asphalt
- covering with bentonite or fibre mats.

The concept of multi-barriers involves the implementation of several types of sealing in a strategy to prevent the formation and inflow of seepage water into the landfill body. Most seepage water that, despite all measures, still occurs and also landfill gas are collected and channelled from the landfill body.

A 2.3 Remediation of the shut-down Georgswerder disposal site in Hamburg

The shut-down Georgswerder landfill, situated on a diked island in the glacial valley of the river Elbe, served as the main disposal site for the waste of Hamburg. In addition to municipal and building site waste, environmentally hazardous industrial waste of liquid, paste-like and solid consistency was dumped in Georgswerder. Until the decommissioning of the landfill in 1979, the dumped waste accumulated on an area of 0.45 km^2 in a pile 40 m high, with a volume of approximately 7 million m^3.
The industrial waste contained residues from the petroleum and petroleum processing industry, chlorinated hydrocarbons (e.g. trichloroethene, tetrachloroethene and hexachlorocyclohexane), solvents (e.g. benzene, toluene, ethylbenzene, xylene), naphthalenes, refining residua, phenolic resin emulsions, sludges, lubricants and heavy metals.
At the landfill site there was neither surface sealing nor sealing of the base so that precipitation could enter the landfill body unhampered and leach out the hazardous substances. Furthermore, owing to the extra load on the landfill body, a water table of slack water formed at an altitude of 14 m above sea-level. Within the slack water, contamination from volatile chlorinated hydrocarbons, benzenes and, to a minor extent, chlorobenzenes occurred. The contamination spread from the slack water into the groundwater.
In 1985, a remediation proposal for the shut-down of the disposal site was compiled and put into practice between 1986 and 1997.
The focus of the remediation at Georgswerder was on the following aspects:

- sealing the surface and thus minimising the mobilisation of pollutants

- reducing the hazardous potential by pumping up the contaminated stack water
- stopping further spreading of the contaminants by the implementation of hydraulic measures and of a slurry wall
- pumping up the leachate water by 3-5 wells with a capacity of 8.5–5 m^3/h
- implementing density separation of the contaminants from the pumped water, with subsequent physical-chemical treatment and flow through a flotation plant to minimise the adsorptive organic halogens
- collecting and dissipating the landfill gas (methane content 60 %) by 39 gas probes with a feed rate of 250–300 m^3/h
- implementing a new combuster and disposal of combustion residues.

The sealing of the landfill surface of Georgswerder was implemented over an area of 0.15 km^2. The liner system is approximately 2 m thick and is composed of six different layers:

- a ca. 0.75 m restoration layer for vegetation at the surface
- geo-fibre mats
- a 0.25 m drainage layer for dissipating the uncontaminated leachate water
- plastic foil (HDPE – High density polyethylene)
- a 0.6 m almost impermeable mineral cover sheet
- a 0.35 m compensation layerof clay and sand–gravel mixture for gas drainage

Subsequent to the remediation measures, procedures for long-term monitoring of the groundwater were installed to control and guarantee the sustainability of the measures.

For the future use of the remediated Georgswerder landfill, several concepts were put forward. The first proposal to use the whole area as a public park with various recreational facilities could not be put into practice because the general safety precautions for such facilities could not be fulfilled. The final solution included the installation of a wind park with three wind power plants on the landfill body. Further, the groundwater purification system on the site is used to treat further cases of contaminated water that might occur in Hamburg or the surrounding area.

A 3 Large-scale projects

After Germany's reunification, serious environmental problems have been revealed in the New States. Following reunification, the former owner of the nationally owned enterprises no longer existed and therefore the properties and thus the financial responsibility were handed over to the Federal Government.
The often massive contamination on those properties represented a substantial risk for private investors so that there was an urgent need to eliminate such obstacles. In order to encourage investments at contaminated sites, in 1992 the Federal Government and the New States drew up an Administrative Agreement on the financing of contaminated site remediation. Under this Agreement, the Federal Government and the States established 21 large-scale projects whereby the financing of the remediation is shared by the Federal Government (75 %) and the New States (25 %). The total cost amounts to more than 3 billion Euros.
The large-scale projects comprise industrial complexes, e.g. the large chemical plants at Leuna, Buna and Bitterfeld-Wolfen, lignite mining areas and dockyards.

The particularly hazardous situations at the project sites result from interacting factors:

- serious and widespread contamination from abandoned industrial sites and from unsecured or insufficiently secured disposal sites with in part unknown pollutant-mixtures
- regionally significant changes in the groundwater systems due to modified water management in former mining areas
- disposals of hazardous substances and radioactively contaminated material from adjacent mining areas.

The aims of the remediation measures in these large scale projects are:

- immediate measures for averting dangers
- remediation and reclamation of landscapes degraded by industrial use or mining
- groundwater protection to guarantee drinking water abstraction
- maintenance of industrial sites including their infrastructure.

A 3.1 Mansfelder Land

The project region "Mansfelder Land" in Saxony-Anhalt had been a centre of copper mining and ore processing since the Middle Ages. At the end of the 20th century, the last copper mines were closed.

Over 800 years of ore mining and ore smelting have led to enormous, although diffuse, contamination of air, soil and water with heavy metals in the entire region. In particular, heavily polluted waste gases and dust emissions from ore smelting caused widespread pollution. Further hazards emanate from sites where sludges and other residues containing heavy metalls from ore processing were dumped.

The safe decommissioning of the mining sites was given top priority followed by immediate measures to prevent further spreading of contaminated dust. In the latter case the surfaces of dust deposits have been sealed.

Further remediation measures comprise mainly the clean-up and/or containment of the main contamination sources. By 2002 three of the six sub-projects had been completed; water protection measures and water monitoring will be continued probably until 2015.

A 3.2 Bitterfeld-Wolfen

The project "Bitterfeld-Wolfen" in Saxony-Anhalt comprises two sub-projects: the chemical industry complex in Bitterfeld-Wolfen and the film processing industry in Wolfen. The two adjacent industry complexes cover a total area of 13 km^2 including 5.5 km^2 of former waste disposal sites.

The beginning of the chemical industry in the region dates back to 1893. In the following 100 years, Bitterfeld-Wolfen developed into one of the most important chemical production centres in Germany. After Germany's reunification, parts of both industry complexes could be privatised.

In the past, up to 5,000 different chemicals, predominantly chlorine-based, were produced in Bitterfeld and Wolfen. Through losses of material during processing, accidents or the dumping of chemical waste in adjacent mining pits, large amounts of different pollutants entered the soil, groundwater and air. With more than 200 million m^2 of contaminated groundwater Bitterfeld-Wolfen is one of the largest known cases of groundwater contamination in the world. Owing to the immense proportions of the so-called "cocktail of hazardous substances" in the groundwater, conventional remediation technologies fail to be effective. The remediation project is therefore focused on decontamination of groundwater and containment of groundwater pollution. The short- and medium-term measures are to prevent the further spread of groundwater pollution and thus avert environmental hazards. The

installed pumping and treatment facilities are dimensioned for the purification of 6 million m^3/year of contaminated groundwater.
Furthermore, *in situ* remediation of contaminated soil has been carried out to a large extent, and either the contamination of former waste disposal sites has been cleaned up or the further spreading of the pollutants prevented by containment measures.

A 4 Remediation and redevelopment of former mining areas

Germany has a mining tradition that dates back hundreds of years. While potash and rock salt resources together with hard coal and lignite are still extracted, mining for copper, uranium and other metals has stopped. Although Germany is still the largest producer of lignite in the world, lignite mining has decreased considerably in the last decade in the mining areas of Eastern Germany. The remediation of former lignite mining areas was and is still one of the main environmental rehabilitation tasks resulting from German reunification.
About 80 % of the mines in the Lusatia Mining Area and Central German Mining Area and most of the refining facilities have been closed since 1990. Only 7 opencast mines were competitive and therefore privatised in 1994. As a consequence, annual lignite production in those areas decreased from >300 megatons in 1989 to 71 megatons in 2000 and 100,000 employees became redundant. On account of this drastic reduction in jobs, priorities in the management of abandoned lignite mining sites include not only classical remediation measures but also economic and social aspects such as job creation and redevelopment of industrial sites.

Main tasks in the remediation of mining sites:

- averting dangers arising from former mining activities, e.g. stabilising slopes
- reclamation of mining sites
- restoring a balanced water regime
- eliminating hazards emanating from groundwater and soil contamination by earlier industrial use

A 4.1 Legal framework

Lignite mining rehabilitation goes beyond the scope of the **Federal Soil Protection Act**. Most of the former mining sites and suspected contaminated sites are subject to the **Federal Mining Act**, which came into force in the New States in 1990. Article

55 of the Federal Mining Act requires mine-owners to rehabilitate abandoned mining sites in such a way that ensures that no risks emanate from land formerly used for mining purposes and takes the public interest into account.
According to the Administrative Agreement on the financing of contaminated site remediation, the ownership of the mines passed into the hands of the Federal Government, so the Federal Government became financially responsible for mining site remediation.
The current third agreement, which will be in effect until 2007, provides for a total budget of approximately 1.4 billion Euros to finance the current cost of remediation measures. The measures are primarily aimed at improving the water balance and at the rehabilitation of infrastructure in these regions. Further payments of 200 million Euros, shared equally by the Federal Government and the Federal States, are going to be made available for measures to prevent impacts caused by the groundwater rise.
The Lusatia and Central German Mining Agency is responsible for the decommissioning of the mining supervision, for the rehabilitation of the former mining sites and for the commissioning of clean-up companies to carry out the remediation measures. The work of the Lusatia and Central German Mining Agency is supervised by the Steering and Budget Commission for lignite mining remediation.

A 4.2 Opencast mining sites

Land consumption by lignite mining was enormous because the lignite deposits consisted of almost horizontal, thin layers. By 1989, land-take by lignite mining activities and associated refinement facilities had added up to 3,500 km^2.
After the closure of many mining sites, more than 1,000 km^2, an area bigger than the city of Berlin, had to be redeveloped. As an area comprising 39 mining sites including 224 former opencast pits was in need of reclamation as a whole, new prospects of landscape design opened up. The recultivated landscape fulfils valuable functions as a recreational area and as a habitat for flora and fauna.

Status of lignite mining remediation in 2001:
About 63 % of the former mining area has already been recultivated, of which:

- 350 km^2 are used for forestry
- 160 km^2 are used as agricultural land
- 97 km^2 are used for water surfaces

A large part of lignite mining remediation was devoted to geo-technical safety. In performing the various measures, the focus was on the remediation and stabilisation of more than 1,000 km of slopes, which corresponds approximately to the extent of Germany in the direction from north to south. About 580 km of man-made and natural slopes, especially in the Lusatia Mining Area, were at risk of slipping and needed to be stabilised.

Up to the end of 2001, 1.3 billion m^3 out of an estimated total of 1.7 billion m^3 of soil had been moved for either constructing or flattening stable slopes and for other measures of landscape design.

A 4.2.1 Water management

Lignite mining in opencast mines required a lowering of the groundwater table to the depth of the lowest lignite seam. As a consequence of water pumpage in the mines, the whole groundwater system and watercourses in the adjacent area were changed.

The main aims concerning water management at former mining sites are:

- compensating for the loss of static groundwater
- flooding the former opencast mining sites
- restoring the water regime to a condition where it is largely self-regulating
- re-activating the retention reservoirs and wetlands.

In 1990, a total water deficiency of 12.7 billion m^3 within the mining areas was recorded. About 8.2 billion m^3 are needed to replenish the groundwater and another 4.5 billion m^3 are needed for flooding the 224 former mining sites. At present 48 % of the pits are already filled. Flooding with surface water from the rivers nearby appears to be the most effective way at present to counteract the impending risk of flooded pits acidifying. Nevertheless, appropriate management and aftercare of the water bodies remains indispensable.

The predicted rise of the groundwater table will affect an area of 2,100 km^2 in the Lusatia Mining Region and of 1,100 km^2 in the Central German Mining Region.

The rising groundwater table increases the risk of groundwater coming in contact with the overlying polluted soil and becoming contaminated itself. This explains the particular urgency of remedial measures.

A 4.2.2 Contaminated sites

The reduction of lignite mining in the Lusatia and Central German Mining Regions led to the closure of many plants for the production and processing of lignite. The legacy of long-term lignite refinement is a vast variety of hazardous substances contaminating soil and groundwater.

More than 1,200 suspected contaminated former mining sites have been registered, of which 60 % are abandoned industrial sites and 40 % former waste disposal sites. Typical abandoned industrial sites in mining areas include former briquetting plants, industrial power stations, gas works, thermal upgrading plants, storage and assembly areas and scrap yards. Contamination at these sites is caused by phenols, polychlorinated aromatic hydrocarbons, petroleum-derived hydrocarbons, BTEX (benzene, toluene, ethylbenzene, xylene), ammonium, sulphonamides and nitrogenous compounds as well as heavy metals. Remediation comprises the dismantling of large installations for lignite conveying, demolition of industrial plants, recycling and disposal of demolition waste, measures to eliminate hazardous substances, soil replacement, sealing of former waste disposal sites to disconnect leachate pathways, pumping up of contaminated groundwater and purification treatment. At present, about 90 % of the refining facilities have been dismantled and undergone remediation.

Another problematic task to be tackled within the scope of lignite mining remediation is the clean-up of waste which had been deposited in abandoned opencast pits. Often these pits were used as dumping sites for residues from the chemical industry, municipal waste, mine tailings and/or construction waste. Mostly the disposal sites possessed insufficient or no sealing of the base so that the hazardous substances could spread easily into the soil and/or groundwater. Furthermore, the remediation of such dumping sites is aggravated by the unusually great thickness and high volume of the waste.

A 5 Abandoned military and armament sites

The political changes in Europe in 1990 involved a general troop reduction and disarmament in Germany. According to the political events, numerous military sites and armament sites in Germany became abandoned. Often these sites had not only been used for military purposes during the period following 1945, but sometimes also since the end of the 19th century.

Military-contaminated sites are abandoned sites where military operations have taken place in the past, i.e. abandoned military facilities which were formerly used

for testing and using military equipment and where during military activities environmentally hazardous substances were handled.

Armaments-contaminated sites are abandoned sites on which facilities for developing, producing, storing and destroying military equipment had operated. The contaminations of the military- and armament-contaminated sites show different inventories of pollutants owing to their historical use. In recent years, the remediation placed emphasis on the identification, on the risk-assessment, on the implementation of the so-far possible remediation measures and on the redevelopment of these sites.

A 5.1 Abandoned military-contaminated sites

The end of the Cold War caused a general troop reduction in Germany. The significant decrease in the number of military personnel and installations of the Allied and German Forces, and the withdrawal of the West Group of the former Soviet Troops (WGT) from East Germany, resulted in around 0.5 million ha of former militarily used land being returned to civil control.

Since the area of military sites is usually not used uniformly, the contamination on these sites is often limited to selected points whereas the remaining areas, especially military training areas, show a surprisingly high biodiversity. The mostly solitary locations of military sites offer enough room for the undisturbed development of many species. Also, except for the occasional military exercises, no other anthropogenic influence is found.

The contamination of abandoned military-contaminated sites corresponds to those found on civil sites and is mainly caused by the same pollutants, such as:

- lubricants and hydrocarbon fuels in the form of petroleum-derived hydrocarbons
- heavy metals
- volatile halogenated hydrocarbons
- BTEX (benzene, toluene, ethylbenzene, xylenes)
- polychlorinated aromatic hydrocarbons.

The contaminations were mostly located at filling stations, car parks, vehicle maintenance and repair facilities, car-washing areas, charging stations for batteries and at refuelling points and/or fuel reloading points. Further contaminated sites were found at waste transfer stations, scrap metal yards, old deposits, landfills, depots for water-endangering substances, airstrips and fly tippings.

Before civil re-use of an abandoned military-contaminated site can be authorised, investigations and, if required, remediation measures must be implemented.
Since most of the contaminations on military sites resemble contaminations of civil sites, the approach and remediation measures are the same. An exception is the historical investigation of abandoned military sites, which differs from the proceedings with civil abandoned sites. Owing to military secrecy and destruction of documents, a document search often produces only insufficient results or no result at all. As a consequence, aerial photographs frequently have to be evaluated. On the basis of aerial photographs from the World War II, information about still existing explosive bodies in the subsurface is obtained. By the comparison with photographs from the subsequent decades, time–space processes and changes at the site, for example deposition of extensive slag heaps or random tippings, can be recognized.

A 5.1.1 Example: WGT sites

According to the Unification Treaty (article 21, paragraph 1), all military sites used by the Western Group of Forces of the former Soviet Union (WGT) based in the former GDR were subrogated to the Federal General Property in 1990. From 1991 to 1994, the withdrawal according to Agreement on Withdrawal of Soviet Troops from Germany took place, leaving 1,026 WGT sites with an area of 256,000 ha to be transferred into the General Property of the Federal Government of Germany. About 12 % of the WGT sites required intermediate action, 32 % needed further investigation and 56 % were not environmentally relevant. These sites were classified into the categories listed in Table X.

Table. Inventory of the 1026 WGT sites in Germany classified according to the type of property (source: Federal Environmental Agency, 1997, UBA-Text 4/97).

Type of property	Absolute number	Relative area (%)
Administration/offices	48	0.1
Housing/barracks	417	7.5
Training areas (training centres, sites used for practical/technical training, driving lessons)	9	0.6
Telecommunications	93	0.4
Airfields, anti-missile positions, anti-aircraft positions	80	7.2
Depots, storage areas, bunkers (e.g. tank farms, ammunition depots, storage areas for chemicals)	117	2.6
Military training areas and gunnery ranges	173	80.9
Repair and maintenance facilities	28	0.3
Other facilities (e.g. bakeries, medical care, etc.)	61	0.1

A 5.2 Abandoned armament-contaminated sites

More than 60 years after the end of World War II, the armament-contaminated sites from World Wars I and II, although partly fallen into oblivion, are still a contemporary issue within the remediation of contaminated sites. In 1995, 3,240 armament-contaminated sites and suspected armament-contaminated sites were registered in a nationwide inventory comprising sites which were used for armament production between 1870 and the end of World War II.

Armaments-contaminated sites include all sites on which armament production took place and on which warfare agents were handled, e.g. former armament production facilities, munition depots, weapon neutralisation grounds, bomb-disposal grounds, decommissioning works and facilities for intermediate or final storage of chemical warfare agents.

Armaments-contaminated sites show a specific range of contamination that obviously differs from that of contaminated civil sites. They contain in general materials with higher potential damage and hazard than found at civil sites owing to the utilization of highly toxic or carcinogenic pollutants for armament production and handling. Such chemicals include in particular chemical warfare agents, explosives, incendiaries and smoke agents, propulsive agents, chemicals added to

warfare agents for tactical purposes, preliminary products and waste products arising in production and as residues from the destruction of conventional and chemical warfare agents.

The contaminations found on abandoned armament sites reach particularly hazardous dimensions since armament production and processing took mostly place during wartime. In those days the production of armaments had the absolute top priority and the impact on the environment during processing was hardly considered. Mostly sewage and waste-intensive methods had been applied. The contaminations were further increased by destruction of the production plants during the War and inappropriate dismantling after the end of War.

국문요약

Introduction

독일의 재통일 이후에 예상되는 오염지역의 수가 급격히 증가하게 되는데 이는 New States 의 심각한 환경문제에 기인한 것이다. 하지만 전체의 10~15%만이 실제적인 정화가 필요하다. 최근에 들어서는 오염지역을 깨끗이 하고 재개발하기 위한 노력들이 행해지는데 주로 복원된 토양이나 지하수를 보전하여 가능한 위험을 막는 것이다.

1. Soil contamination

일정한 수준 이상의 토양오염은 먹이사슬에 부정적인 결과를 일으켜 결국에는 인간의 건강에 영향을 끼친다.

1.1 Local soil contamination

지역적인 오염은 일반적으로 광산, 산업시설, 쓰레기 매립 그리고 현재 가동중이거나 폐쇄된 시설과 연관되어있다. 불모지를 매립하는 것 또한 중요한 연관성을 가지는 오염활동이 될 수 있다. EU 의 오염지역의 숫자는 300,000 에서 1,500,000 에 이른다. 이처럼 큰 범위를 가지는 이유는 오염지역에 대한 공통적인 정의가 부족하고, 허용될 수 있는 위험수치, 보호 대상, 노출 지표가 다르기 때문이다. 지식을 공유하고 깨끗이 할 장소를 정하는 것이 오늘날의 오염문제를 해결할 중대한 방향이다. 그러나 더욱 심각한 오염에 대해서는 미래의 목표가 필요하다.

1.2 Diffuse soil contamination

암모니아와 다른 질소 침전물, 경작 습관, 비료나 동물사료의 중금속 등이 원치않은 토양의 비옥화를 가져온다. 토양오염 확산에 대한 비용은 토양 그 자체로는 그다지 많지 않다. 하지만 문제는 토양의 수용한계를 지나쳤을 때이다. 지금까지 측정된 정확한 자료는 없지만 유기 복합물, 살충제, 식물 영양제 그리고 물속의 중금속을 처리하는데는 비용이 많이드는 걸로 알려져 있다.

2. Management of contaminated sites

2.1 Legal framework

오염된 땅과 지하수의 관리는 연방법을 필요로 한다. 1999 년에 독일 연방정부는 연방 토양 보호 법령을 발표했다. 법령의 주된 목표는 토양을 그 기능에 해가 되는 영향으로부터 보호하고 토양오염을 막으며 버려진 오염지역을 청정화하는 것을 규제하는 것이다. 오염된 지역은 폐쇄 쓰레기의 재활용과 처분을 위한 시설과 환경적으로 해로운 물질이 사용된 적이

있는 폐쇄된 시설물이나 지역을 말한다. 오염가능 지역은 개인이나 일반적인 공공에 대해 토양에서의 해로운 변화나 다른 해가 존재할 가능성이 있는 구체적인 땅이다. 군사나 무기 생산용으로 쓰인 장소도 여기에 포함된다. 오염자 부담의 원칙은 오염을 일으킨 사람이 책임을 지는 것을 원칙으로 한다. 오염자를 뛰어넘어서 소유자 또한 책임이 있다.

3. Programmes and Networks

많은 프로그램들은 기술개발과 네트워크를 도와주었고 오염지역의 처리에 있어 국제적인 협력을 이끌어 주었다. 효과적인 국제 협력의 예가 혁신적인 치료기술에 대한 연구를 한 NATO/CCMS(Commotee Programme on the Challenges of Modern Society)이다. 이외에도 CARACAS(Concerted action initiative on risk assessment for contaminated sites), SAFIRA(Remediation Research in regional contaminated aquifers), CLARINET(Contaminated Land Regabilitation Network for Environmental Technologies), RUBIN(PRB - Premeable Reactive Barriers) 등이 있다. 독일의 구체적인 치료 계획의 예는 부록에 언급되어 있다.

4. European Soil Protection Policy

유럽연합의 6th 환경프로그램의 목표중의 하나가 부식과 오염으로부터 토양을 보호하는 것이다. 유럽에서 토양에 주로 해를 끼치는 것은 다음과 같다.

부식

유기물질의 감소

토양오염

soil sealing(주택이나 도로, 다른 기반 시설로 인해 토양이 덮임)

토양 압밀(무거운 기계류, 가축방목, 스포츠 활동 등의 사용을 통한 기계적인 압력)

토양 생물의 다양성의 감소

salinisation(나트륨, 마그네슘, 칼슘으로부터의 가용성 염류의 과도한 축적), 홍수, 산사 태

환경정책에서 새로운 법령이 기존의 것을 보충할 것이다.

2002 : 4th Daughter Directive on air quality and a directive on mining waste

2003 : 토양의 지속가능한 사용에 초점을 둔 계획과 환경에 관한 하수 침전물 지령과 전달의 개정

2004 년까지 : 퇴비와 생물학적인 쓰레기에 관한 지령

5.Reducing the Land Consumption

지난 3년에 걸쳐 주거와 교통의 용도로 쓰인 토지가 지속적으로 증가하고 있다. 현재의 추세로 토지개발이 계속된다면 목표는 이루어질 수 없게 된다. 따라서 환경목적에 응하기 위해서는 다양한 방법들이 행해져야 한다. 토양관리를 개선하기 위해서 건설 계획 중에 토양의 기능에 대한 평가가 이루어져야 한다. 다른 토지의 이용에 관한 할당이 필요하다. 미개발 지역의 건설을 허가하기보다는 현존하는 주거지역의 할당은 미개발 지역의 건설을 격려차원에서 장려되어야 한다.