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A Survey of Environmental Needs and Innovative Technologies in Germany

Charles F. Voss and William J. Roberds
Golder Associates Inc.
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A SURVEY OF ENVIRONMENTAL NEEDS AND INNOVATIVE TECHNOLOGIES IN GERMANY

Charles F. Voss and William J. Roberds, Sc.D.
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Sandia Contract No. 87-3497

ABSTRACT

The International Technology Program (ITP), formerly the International Technology Exchange Program (ITEP), of the Department of Energy's (DOE's) Office of Environmental Restoration and Waste Management (EM) is responsible for promoting: (1) the import of innovative technologies to better address EM's needs; and (2) the export of US services into foreign markets to enhance US competitiveness. Under this program: (1) the environmental restoration market in Germany was evaluated, including the description of the general types of environmental problems, the environmental regulations, and specific selected contaminated sites; and (2) potentially innovative environmental restoration technologies, either commercially available or under development in Germany, were identified, described and evaluated. It was found that: (1) the environmental restoration market in Germany is very large, on the order of several billion US dollars per year, with a significant portion possibly available to US businesses; and (2) a large number (54) of innovative environmental restoration technologies, which are either commercially available or under development in Germany, may have some benefit to the DOE EM program and should be considered for transfer to the US.

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EXECUTIVE SUMMARY

One of the primary goals of the Department of Energy's (DOE's) Office of Environmental Restoration and Waste Management (EM) is to remediate waste sites throughout its complex and bring the facilities into full compliance with US environmental regulations by 2019. Within EM, the Office of Technology Development (OTD) has the charter to develop technologies to support the cleanup goal. In addition to developing and demonstrating US technologies, OTD is looking for foreign technologies that may be suitable for addressing the DOE's needs. OTD initiated the International Technology Exchange Program (ITEP) in 1991 to cooperate with foreign governments, industries, and educational institutions to identify worldwide needs for remediation of waste sites and evaluate and transfer promising technologies among the various countries involved. Sandia National Laboratories (SNL) has had the primary role of ITEP integrator, directing and coordinating the activities of various contractors.

During its first year, ITEP targeted several countries in Europe to begin its search for new or innovative technologies. This study documents a study of Germany's environmental restoration needs and technologies that have been used or are being developed to address these needs. The study was performed by Golder Associates Inc. in Seattle, Washington and was supported by Golder Associates Umwelttechnik GmbH in Celle, Germany.

This study utilized a number of sources to investigate the environmental problems and technologies in Germany including literature reviews of technical publications, databases of environmental-related information, and direct contacts with representatives from government ministries, national research establishments, universities and industry in Germany. The search was limited to environmental restoration technologies; it did not include waste management technologies. The technologies are grouped by generic categories related to the DOE's environmental restoration and waste management program.

There are serious environmental problems in Germany resulting from decades of heavy industrial production and general indifference towards the environment, particularly in the former German Democratic Republic (eastern Germany). Western Germany has an estimated 99,300 potentially hazardous waste sites. Recent estimates are that 50% of the potentially hazardous abandoned industrial waste sites and 10% of the potentially hazardous abandoned waste disposal sites pose a health risk potential to the surrounding populations. Cleanup cost estimates range from DM 17,000 to 100,000-million. There are an additional 47,100 contaminated sites in eastern Germany with a majority of the sites in the area of Leipzig, Halle, Bitterfeld, and Merseburg. The cost for environmental cleanup in these areas could be as much as DM 11,000-million by the year 2000.

Beginning in the 1970s, the public's attitude about environmental issues changed dramatically in Germany. Protecting the environment is now one of the greatest concerns of the German public. In the 1991 federal budget, the German government allocated over DM 6.5 billion for environmental protection and improvement in Germany. Of this, approximately DM 1.5 billion is being spent on research and development. This has resulted in a vigorous market for "environmental firms" in Germany and a significant effort to develop new and innovative technologies. There are over 4,000 companies involved in the environmental market in Germany employing an estimated 440,000 people.

While there is a large investment in environmental restoration technologies in Germany, the number of technologies involved is relatively small, i.e., there are few disparate methods in any of the categories. A majority of the research programs attempt to improve a technology instead of developing ones that are fundamentally different.

Fifty-four of the technologies evaluated are considered to be innovative. A majority (52%) are associated with waste treatment such as extraction processes. The next largest categories are site waste removal (13%) and in situ containment (11%) with the remaining technologies being fairly evenly distributed: in situ treatment (7%); waste disposal (7%); and site characterization (7%). The exception is the waste transportation/storage category, which contains only one technology.

Few of the technologies identified are unique to Germany. The rapid transfer of information via journal articles, symposia, etc., and the large market in environmental restoration has resulted in technologies being fairly ubiquitous. Government research organizations often have cooperative research areas with their counterparts in other countries sharing ideas and breakthroughs. The companies and institutions developing technologies that are really new and promising are unlikely to divulge information until their product is mature enough to bring it to market.

1 INTRODUCTION

One of the primary goals of the Department of Energy's (DOE's) Office of Environmental Restoration and Waste Management (EM) is to remediate waste sites throughout its complex and bring the facilities into full compliance with US environmental regulations by 2019. Within EM, the Office of Technology Development (OTD) has the charter to develop technologies to support the cleanup goal. In addition to developing and demonstrating US technologies, OTD is looking for foreign technologies that may be suitable for addressing the DOE's needs. OTD initiated the International Technology Exchange Program (ITEP) in 1991 to cooperate with foreign governments, industries, and educational institutions to identify worldwide needs for remediation of waste sites and evaluate and transfer promising technologies among the various countries involved. Sandia National Laboratories (SNL) has had the primary role of ITEP integrator, directing and coordinating the activities of various contractors.

During its first year, ITEP targeted several countries in Europe to begin its search for new or innovative technologies. This study documents a study of Germany's environmental restoration needs and the technologies that have been used or are being developed to address these needs. The study was performed by Golder Associates Inc. in Seattle, Washington and was supported by Golder Associates Umwelttechnik GmbH in Celle, Germany. The following approach was used to perform the survey:

- identify generic waste management and environmental restoration needs and activities relevant to the DOE complex;
- identify the nature and extent of environmental restoration problems in Germany; and
- identify mature and developing German technologies for remediating contaminated sites.

The survey utilized several resources for collecting the information: (1) federal and state ministries were contacted to learn about environmental problems throughout Germany and research and development programs in place for developing new environmental technologies; (2) technical universities and research institutes throughout Germany were contacted; (3) literature reviews were performed in Germany and the US to identify references to specific environmental restoration projects in Germany which utilized non-standard technologies; and (4) several German and US databases were searched for relevant information.

The information in this report is presented as follows. Section 2 provides a synopsis of environmental problems in Germany. Section 3 presents an overview of the environmental regulations and the governmental structures that exist. These factors have considerable influence over the types of technologies being developed in Germany and account for differences in the structure and implementation of environmental regulations in Germany and the US. Section 4 contains tables of innovative German technologies. The technologies are grouped according to generic waste management and environmental restoration needs and activities categories relevant to the DOE complex. A list of agencies associated with German environmental issues is provided in Appendix A. Appendix B contains detailed information on a cross section of 15 of the most serious environmental contamination problems facing Germany.

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2 ENVIRONMENTAL OVERVIEW OF GERMANY

Germany is a country of geographical and historical complexity. It contains a range of peoples speaking variants of the German language over a range of Central Europe that has had a great diversity of political forms. In fact, for most of "Germany's" history, the country has included non-German speaking peoples. Germany is formed of regions which have had their own existence as independent provinces or principalities. As a result, there are striking regional variations based more on political, cultural and socioeconomic history than on geography. In more recent times, Germany has meant either the Federal Republic of Germany, or West Germany, with its capital in Bonn, or the German Democratic Republic, or East Germany, with its capital in Berlin. With the unification of the two Germanies, it is even more difficult to describe the country in general terms. These areas will hereafter be referred to as western and eastern Germany.

Topographically, the country extends from the coasts of the North Sea and Baltic Sea through the north German plain until the land is broken by the hillier country of the central German uplands and then continues through the gently rolling hills of southern Germany to the foothills of the Alps on the borders of Austria and Switzerland. The climate varies from mild, wet Atlantic weather in the north and west to a drier climate in the south and east with cold, snowy winters and hot summers. Natural resources in the country are also variable. There are vast deposits of low-grade lignite in the eastern portion in the Halle-Leipzig area. Until recently, this area produced about one-third of the world's total production of brown coal. Higher grade bituminous coal deposits are mined in the Ruhr area and account for most of the energy production in the country. There are small amounts of natural gas and oil in the country but they are insufficient to meet the current energy needs. These needs are offset somewhat by the use of nuclear power stations in western Germany. Other mineral deposits include iron, lead, copper, zinc, and potash.

With the exception of Belgium, the Netherlands, and possibly the United Kingdom, Germany has the highest population density of the European countries with approximately 222 people per km^2. Eastern Germany's population remained almost static after the end of World War II at around 17 million while western Germany's population rose by 50% to around 62 million. However, the average annual population growth rate has been declining recently with a projected rate of -74,000 people per year over the period from 1995 to 2000 (World Resources Institute, 1992). Eastern Germany's citizens tended to remain residents of medium-sized towns and smaller communities with a relatively low population density while in western Germany there was a higher degree of urbanization. The country consists of 16 states, 11 in western Germany and five in eastern Germany. Table 2-1 provides summary information about the states, including their association prior to unification, the population, surface area, and capital.

The economy in western Germany relied much more on industry than the more agriculturally based eastern Germany. At the time of economic unification, the gross domestic product was $23,500 per person in western Germany compared with $8,040 in eastern Germany (The Economist, 1992). Figure 2-1 shows the population density and gross domestic product in each of the states.

Following monetary union, the economy of the eastern German states collapsed. There are three main reasons given for the crash (The Economist, 1992). When the east German currency was converted to the west German Deutsche Mark, the real wages being paid increased dramatically, exceeding in many instances, the income that could be generated from sales of the products being produced. Second, demand for eastern German goods dropped profoundly after monetary union. During the post-war era, industrialization in eastern Germany increased significantly, but the quality of goods was considered poorer than goods produced in western Germany. Following unification, eastern German residents had access to western goods and currency, and demand for goods produced in the east plummeted. In addition, the trading arrangement between Soviet and eastern European states collapsed, ending demand for approximately two-fifths of eastern

TABLE 2-1. GENERAL INFORMATION ON GERMAN STATES

State (German spelling in parentheses)	Former Association	Population (in millions)	Area (sq. km.)	Capital
Baden-Württemberg	West	9.5	35,752	Stuttgart
Bavaria (Bayern)	West	11.2	70,552	München
Berlin	East/ West	3.4	883	Berlin
Brandenburg	East	2.6	29,000	Potsdam
Bremen	West	0.7	404	Bremen
Hamburg	West	1.6	755	Hamburg
Hesse (Hessen)	West	5.6	21,114	Wiesbaden
Mecklenburg-Western Pomerania (Mecklenburg-Vorpommern)	East	2.1	26,700	Schwerin
Lower Saxony (Niedersachsen)	West	7.2	47,000	Hannover
North Rhine-Westphalia (Nordrhein-Westfalen)	West	17.1	34,068	Düsseldorf
Rhineland-Palatinate (Rhineland-Pfalz)	West	3.7	19,849	Mainz
Saarland	West	1.0	2,570	Saarbrucken
Saxony (Sachsen)	East	4.9	17,700	Dresden
Saxony-Anhalt (Sachsen-Anhalt)	East	3.0	20,300	Magdeburg
Schleswig-Holstein	West	2.6	16,000	Kiel
Thuringia (Thuringen)	East	2.7	15,200	Erfurt
Totals for all of Germany		78.9	357,847	

Germany's exports. Support of the eastern economy is now provided by western Germany. In 1991, government transfers to the eastern states were around DM 170-billion, compared with DM 30-billion collected in taxes from these states, resulting in a net shift of DM 140-billion (The Economist, 1992). About a quarter of this money is going into investment in the east, with the rest spent on entitlement.

Prior to unification, businesses in eastern Germany were owned and operated by the state. Since unification the Treuhand, a federal government agency, has the responsibility of privatizating, restructuring, and closing down former state industries. The Treuhand was initially responsible for approximately 4 million jobs and 12,000 businesses. About half of the businesses have been sold to date. In addition, the Treuhand has taken on the debts incurred by the formerly state-owned businesses. Included with these debts are the significant environmental damages caused by the businesses. Nevertheless, western German companies are investing capital to develop industries in the east, including many of the major automobile manufacturing and chemical companies.

From 1949 until 1990, when Germany was divided into the separate countries of East Germany and West Germany, each country controlled environmental and industrial regulation separately. Environmental regulations and health standards were essentially nonexistent in eastern Germany, and the resulting environmental damage is severe. The shorter life expectancy at birth in eastern Germany, 74.5 years compared with 76.0 years in western Germany (World Resources Institute, 1992), may likely reflect differences in environmental quality, particularly in air quality. Referring

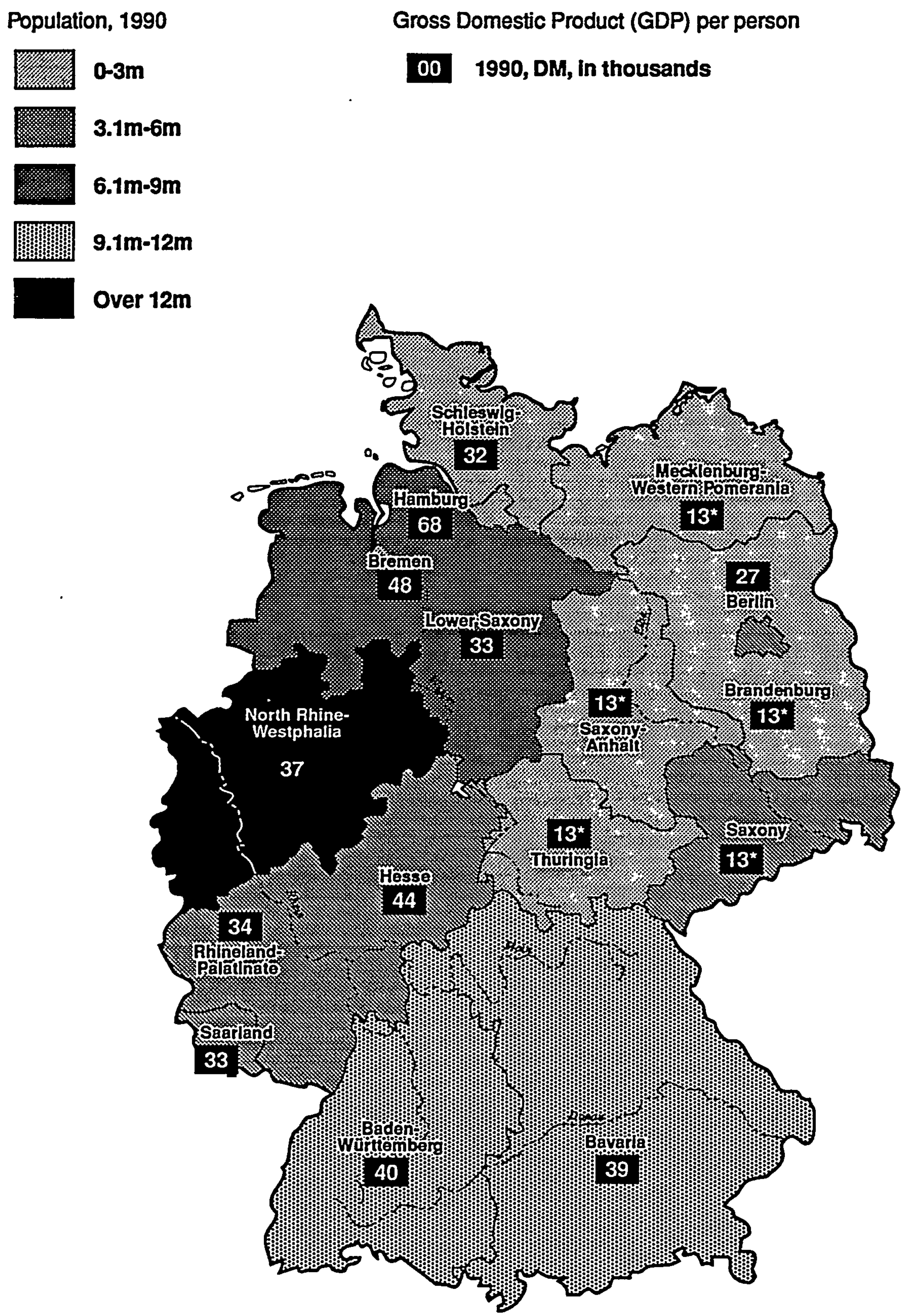

FIGURE 2-1
POPULATION DENSITY AND GROSS DOMESTIC PRODUCT IN GERMAN STATES
SANDIA/ITEP/WA

* Average GDP per person for former Eastern Germany in 1990.
Source: The Economist, May 23, 1992

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to environmental problems in eastern Germany, Fritz Franzmeyer of the German Institute for Economic Research stated, "The problem is primarily the result of a faulty, mismanaged economic system. Production, without restraints on damage to the environment, appears to have been the only consideration" (Christian Science Monitor, 1990). The Federal Ministry for the Environment has identified four factors causing the serious level of environmental pollution: (1) a very inefficient system of energy supply based extensively on lignite; (2) an outdated production system; (3) a poor infrastructure for waste management; and (4) a large-scale industrial farming structure using large amounts of chemicals and vast, continuous tracts of land (Federal Ministry for the Environment, 1992).

In recent years, environmentalism has become a powerful factor in German politics, as evidenced by the rise of the Green Party in the early 1980s. Significant media attention has been directed toward environmental problems. Since unification, the severe level of environmental contamination in industrial areas of eastern Germany has received much publicity. Prior to unification, the West German parliament had already approved an expenditure of $59 million on 21 priority remediation projects in eastern Germany (Christian Science Monitor, 1990). Since unification, the German government has allocated additional funding for immediate use on contaminated site cleanup in eastern Germany. Recent funding includes DM 500-million spent on immediate measures for over 600 projects in eastern Germany in the second half of 1990, DM 400-million spent on immediate measures in 1991, and an additional DM 400-million available for immediate measures in 1992. DM 250-million has been allocated for reducing pollution in all of Germany, with a large percentage of this going to eastern Germany, and up to DM 1,700-million was available in 1991 for developing environmental infrastructure at the local level, including assistance measures and loans (Federal Ministry for the Environment, 1992).

The Federal Ministry for the Environment has recommended several immediate and medium-term measures to aid government officials in making decisions on ecological recovery in eastern Germany. The recommended immediate measures include: (1) surveys of drinking water wells and closure of wells with nitrate pollution over 90-mg/l; (2) installation of smog monitoring systems; (3) closure of highly polluting facilities with poor potential for upgrading; (4) substitution of lower emission fuels for high-sulfur lignite; (5) securing and possible closure of waste management facilities and waste deposits with acute hazards; (6) setting restrictions for soils polluted by heavy metals, toxic organic substances, and radioactive substances; (7) initiation of remedial measures where residential areas are polluted by dioxin in excess of 1,000-ng/kg; and (8) restrictions on the use of soils heavily polluted by heavy metals and organic compounds, including discontinuation of farming in the vicinity of metallurgical and waste incineration facilities. The medium-term measures include: (1) updating antiquated water supply facilities with modern treatment technologies; (2) modernization of old piping systems with high water losses; (3) construction or upgrading of municipal and industrial sewage treatment plants; (4) refurbishment of the estimated 60 to 70% of existing sewage systems with structural defects; (5) development of municipal waste collection and transport mechanisms; and (6) construction of waste treatment, recycling, storage, and disposal facilities (Federal Ministry for the Environment, 1992).

2-1 Contributing Factors in Environmental Contamination

2-1-1 Major Population Centers and Industrial Areas

Historically, the level of environmental contamination has risen with increased population and industrialization. Western Germany is highly industrialized, and manufacturing is the most important contributor to the economy. Important industries include mechanical and electrical engineering and manufacturing, chemical production, textile and clothing manufacturing, and production of automobiles and other transport equipment. Mining accounts for a small portion of the domestic product. Prior to reunification, eastern Germany had the most developed industrial sector in eastern Europe. However, relative to western industry standards, much of the technology in place was antiquated and inefficient. Important industries in eastern Germany included engineering and manufacturing, chemical production, electronics, and metallurgy. Mining of lignite, potash, uranium, and copper has also contributed to the economy.

The major population and industrial regions in Germany, and consequently, the areas expected to have the highest concentrations of hazardous waste sites, are outlined below.

Major industrial areas in western Germany include:

- The Rhine-Ruhr region, including the cities of Essen, Dortmund, and Düsseldorf, has the highest population density in Germany and is the largest industrial area in continental Europe. Chemical production is the largest industry in the area, employing approximately 200,000 people (Chemische Industrie, 1991). Other industries include textile, paper, automobile, galvanizing, pharmaceutical, and plastics manufacturing, engineering, and electronics (Reuter, 1991).

- The Rhine-Main area, including the cities of Frankfurt, Mainz, and Wiesbaden, is the second largest industrial area in Germany. Like the Rhine-Ruhr region, chemical manufacturing is important in this area.

- The Rhine-Neckar region, centered around Mannheim and Ludwigshafen, is also a large chemical production area and includes the largest chemical plant in Germany, operated by BASF at Ludwigshafen.

- The industrial area surrounding Stuttgart is home to numerous industries, including automobiles, electronics, and precision instrument manufacturers.

- The other principal western German cities of Hamburg, Bremen, Cologne, München, and Nuremberg-Fürth have significant industrial bases.

Major industrial areas in eastern Germany include:

- The Leipzig area, including heavy industrial development in Bitterfeld, Halle, and Merseburg, is the most severely polluted area in eastern Germany.

- The upper Elbe Valley, including the city of Dresden, is a large industrial center.

- The Lusatian lignite mining and energy production area is centered on Cottbus, southeast of Berlin near the Polish border. Cottbus is also a chemical production center.

- The Mansfeld region west of Halle is a copper production area.

- Rostock was the principal port in eastern Germany and is the center of industry on the Baltic Coast.

Prior to the 1970s, environmental regulations were minimal in both East and West Germany. However, by the time unification occurred, vast differences in environmental regulation and technological development existed between eastern and western Germany, and more recent sources of contamination can generally be expected in eastern Germany.

Possibly the most severe environmental damage in Germany is found in the area around the city of Bitterfeld, a heavily industrialized region in Saxony-Anhalt. Industries in this area include chemical manufacturers, a large cellulose factory, and open-pit coal mines. Since unification, the most damaging facilities have been shut down, including the cellulose factory responsible for discharge of 20-tonnes per day of waste organics into an abandoned open-pit mine, producing a half-mile-long, foul-smelling pond known locally as Silver Lake.

In the Bitterfeld area, the public health has been seriously affected by contamination of drinking water supplies and the atmosphere by local chemical industries. Serious complaints of bronchitis and chest pains from the Bitterfeld area are three times greater than from any other part of eastern Germany (The Independent, 1991). Statistics for the Bitterfeld area indicate that only 10% of children less than three years old are considered to have normal health. In the past, the school children from the Bitterfeld region were sent to islands in the Baltic Sea for one month to revitalize them, because of a study indicating that children suffered fewer and less frequent periods of bronchial and other respiratory problems after returning from Baltic vacations. Other studies show that bone development in Bitterfeld children lag up to eight months behind normal.

Because many industries in eastern Germany used old, inefficient technology without pollution controls, many facilities have been closed since unification, resulting in the loss of more than 80,000 jobs in the Bitterfeld area alone. The lack of pollution controls is illustrated by the following examples:

- Brown coal power plants in the Bitterfeld area produced approximately three times the amount of sulfur, carbon, and nitrogen gases produced each year in the entire area of western Germany. Atmospheric sulfur levels in the region have been reported to be over 100-times the official health limit. Health effects from the pollution in the area are evident and various segments of the population suffer from related illnesses (Reuter Newswire, 1990).

- In Merseburg, the Buna Chemical plant operated without any emission control devices and released effluent into the Saale River, a tributary of the Elbe (Christian Science Monitor, 1990).

Power generation facilities associated with industries and cities can be significant sources of environmental contamination and/or hazardous wastes. For example, high-sulfur lignite coal resources are abundant in eastern Germany and have served as the primary energy source. Prior to unification, approximately 70% of East Germany's energy was derived from burning high-sulfur lignite with poor emission control, causing high levels of air pollution. The mining and processing of lignite have also resulted in additional environmental damage. Large mining areas within Brandenburg, Saxony, and Saxony-Anhalt have been strip mined. A land restoration program was recently begun, and Germany plans to spend around DM 25-billion for environmental cleanup in these regions. Restoration plans include the landscaping of slag heaps and recultivation of contaminated soil. The duration of plan implementation is projected to be 20-30-years (Reuter Newswire, 1991).

Germany has more than 20 nuclear power plants producing radioactive waste products that have not yet been stored in a "permanent" repository. At least one of the two Soviet-made nuclear power plants in eastern Germany, specifically located at Greifswald, has been shut down for safety reasons. Prior to unification, East and West Germany followed different policies regarding the handling, storage, and disposal of radioactive wastes. Since unification, the Atomic Energy Act policies followed in western Germany will be applied to all wastes generated or currently stored within Germany. The disposal policy requires that all radioactive wastes be deposited in deep geologic structures. This includes spent fuel which could not be economically reprocessed as well as all non-high-level wastes. Mixed wastes are not recognized as a separate waste category by the

German government and are simply treated as radioactive waste (Battelle Pacific Northwest Laboratories, 1991).

Figure 2-2 depicts the location and type of power generation facilities in Germany producing over 100-MW, as of 1989. Energy sources for the facilities include hard coal, oil and gas, soft coal, heating oil, nuclear hydroelectric, and co-generation.

2-1-2 Military Installations

East and West Germany were heavily militarized, including large numbers of American and other North Atlantic Treaty Organization (NATO) troops and Soviet troops. Since unification, an agreement has been reached for withdrawal of former Soviet troops and the US has agreed to reduce operations and troops. Additional bases are operated by Germany, and other pre-World War II sites also exist. The numerous military bases in Germany, reportedly have substantial environmental problems, primarily because of poor chemical handling practices. Suspected contaminants at military installations include fuels, degreasers, and munitions.

The US had 47 active installations in western Germany and Berlin as of July 1991, including 35 Army and 12 Air Force bases. Most of these bases are located in southern Germany in Bavaria, Baden-Württemberg, Hesse, and Rhineland-Palatinate. The US Air Force has acknowledged that its operations have polluted surface or groundwater at every one of its bases in Germany, and the US Army has identified more than 350 suspected contamination sites within the country (Grossman and Shulman, 1991). Several examples include:

- In 1989, 300,000-gallons of jet fuel leaked from underground piping at Rhine-Main Air Base into the aquifer providing water to Frankfurt. A soil and groundwater remediation program is in progress, which West German officials expect to take at least five years and $15 million to complete (Los Angeles Times, 1990). Also at this base, runoff from a paint stripping facility, a repair yard, and aircraft maintenance areas had drained directly into surrounding soil.

- At Bitburg Air Base in Rhineland-Palatinate, organic waste, chemicals, and solvents flowed into the Kyll River and feeder streams for many years because of inadequate sewage treatment facilities. The Air Force recently completed a new treatment plant in response to complaints by German authorities. In addition, fuel storage and piping systems have been replaced because of extensive leakage problems (Los Angeles Times, 1990).

- At a large US Army base in Mannheim, trichloroethylene (TCE) and other solvents used to clean vehicles infiltrated the soil and were detected in a nearby water supply well. TCE and similar solvents are heavier than water, adding to the difficulties in performing site remediation. A pump-and-treat operation is in progress. Cleanup costs for this site are estimated to exceed $10-million over a 10-year period (Grossman and Shulman, 1991).

- A tank at a US Army base near Karlsruhe has leaked 265,000-gallons of oil, most of which has migrated off-site. At least $9 million has been spent on remediation, with more work required to achieve cleanup (Los Angeles Times, 1990).

No definitive information has been obtained concerning environmental problems at German, non-American NATO, or Soviet bases in Germany. However, it is expected that waste management practices at these bases were similarly poor, and problems with solvent and fuel releases are expected to be common. Other hazardous or radioactive chemical releases and ammunition

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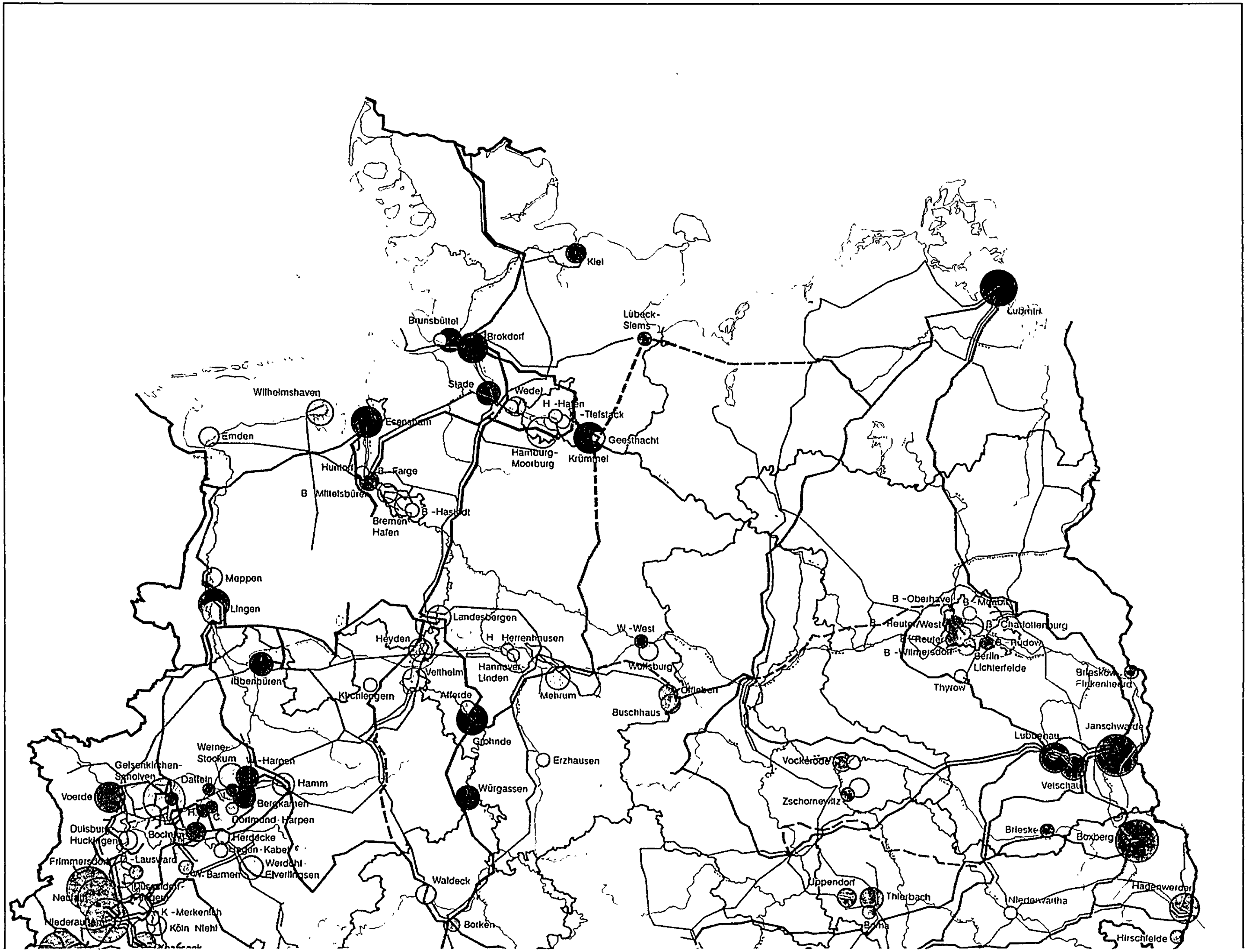
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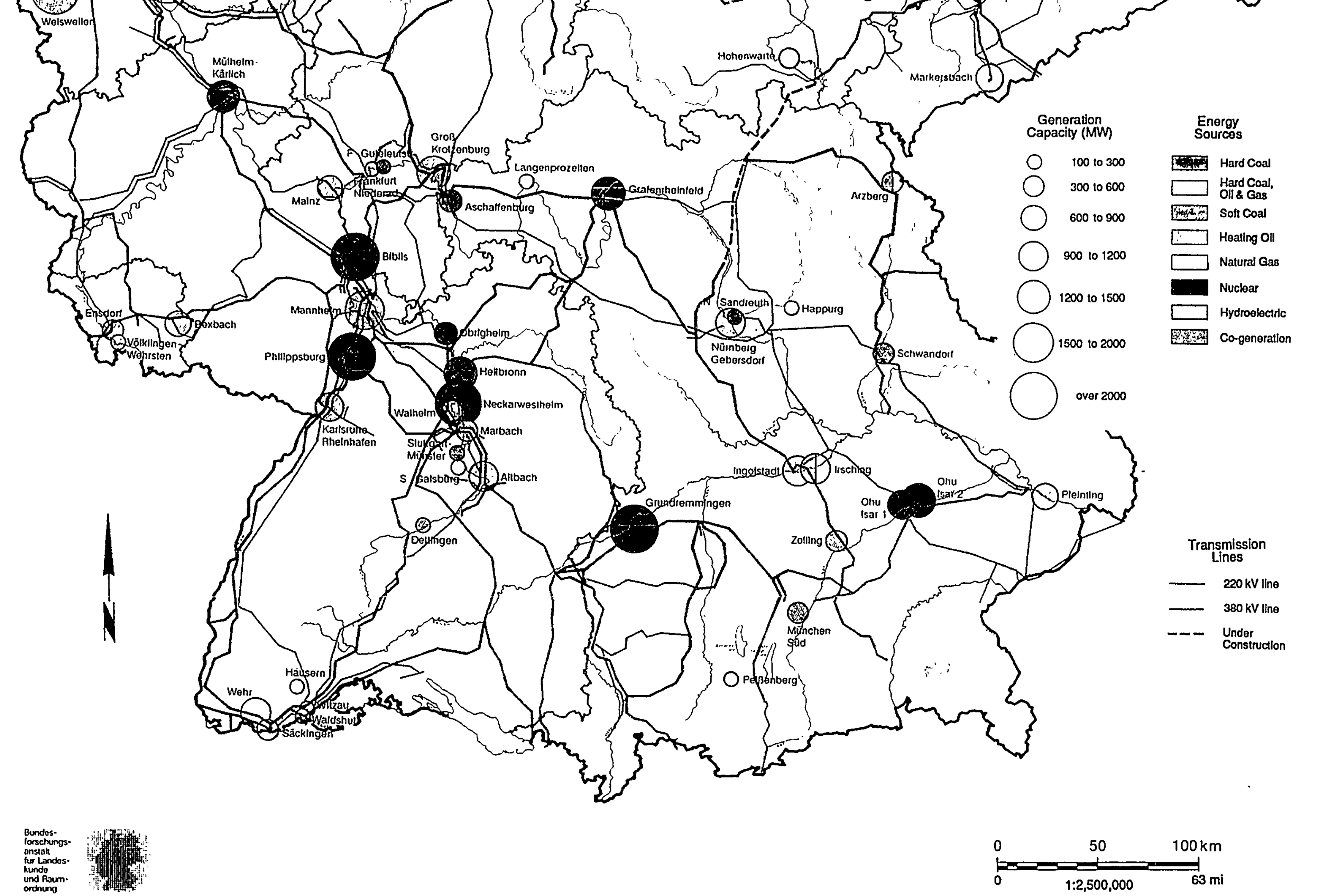
Buschhaus
Ibbenbüren
Kirchlengern
Afferde
Grohnde
Erzhausen
Würgassen
Waldeck
Borken
Hamm
Werne-
Stockum
Gelsenkirchen-
Scholven
Datteln
Bergkamen
Dortmund-Harpen
Voerde
Duisburg-
Huckingen
Herdecke
Hagen-Kabel
Werdohl-
Elverlingsen
Frimmersdorf
W.-Barmen
Neurath
Niederaußem
K -Merkenich
Köln Niehl
B -Oberhavel
B -Moabit
B -Reuter/West
B -Charlottenburg
B -Rudow
B -Wilmersdorf
Berlin-
Lichterfelde
Thyrow
Brieskow-
Finkenheerd
Janschwalde
Lübbenau
Vetschau
Vockerode
Zschornewitz
Brieske
Boxberg
Hagenwerder
Hirschfelde
Niederwartha
Thierbach
Lippendorf
Borna



Source: (Umweltbundesamt, 1992)

FIGURE **2-2**

PUBLIC POWER GENERATION FACILITIES IN GERMANY OVER 100 MW, 1989

DOE/ITEP/WA

PROJECT NO. 913-1248.500 DRAWING NO. 43904 DATE 8/24/92 DRAWN BY TK

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disposal are likely to have occurred. At the end of February 1991, Klaus Topfer, the German Environmental Minister, said contaminated military sites left by the Soviet Army have been found in eastern Germany (Haznews, 1991c). Funding has not been appropriated by the German government to address problems at former Soviet bases, except in cases of immediate danger.

2-1-3 Waste Treatment and Disposal Facilities

Waste treatment and disposal facilities can be significant sources of contamination, especially those that have been in operation for many years. For example, at many locations throughout Germany, old quarries were used for waste disposal without regard to design or hydrogeologic considerations. Landfills were the primary waste disposal mechanism in eastern Germany, with generally small and unorganized sites operated without observing the "usual" standards (Federal Ministry for the Environment, 1992).

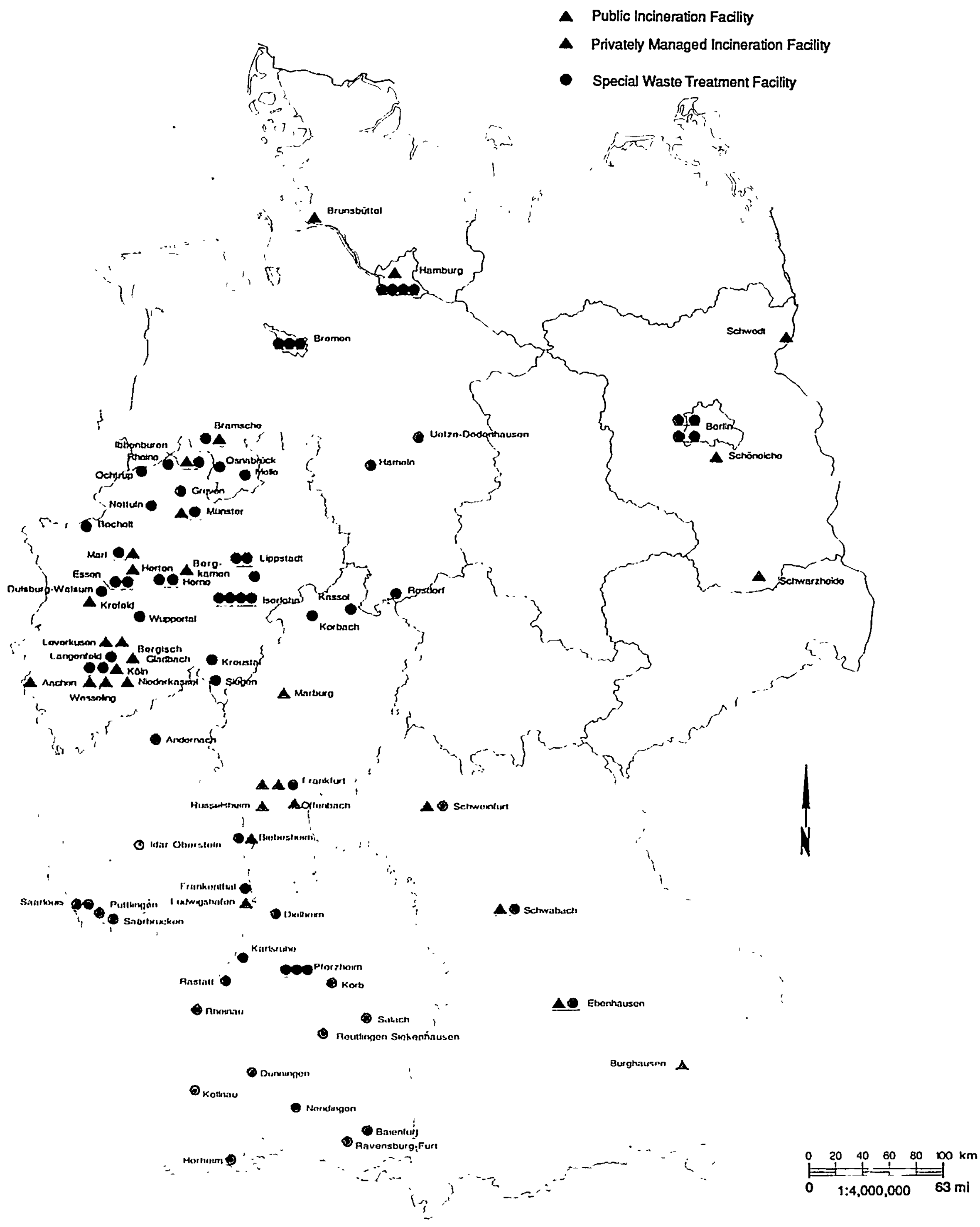
Figure 2-3 presents locations of special waste treatment and incineration facilities in Germany. The treatment facilities shown are for pretreatment prior to incineration or disposal. Treatment includes acid neutralization, flocculation, oxidation or reduction, dewatering, floatation, emulsion separation, or osmosis. Incineration capacity is approximately 800,000-metric tonnes per year. The highest density of facilities is in the Rhine-Ruhr area, associated with the large industrial base in that region.

In 1987, approximately 31 million metric tonnes of household refuse and industrial wastes similar to household refuse, and approximately 152 million metric tonnes of manufacturing and medical wastes were produced and disposed. These figures include an estimated 10-million metric tonnes of hazardous waste (Federal Ministry for the Environment, 1992).

Figure 2-4a shows locations for land-based waste disposal and composting facilities in Germany. Figure 2-4b presents a list of the facility names by state; note that there are no facilities in the states of Bremen, Berlin, or Hamburg. Facilities are classified by their location (eastern or western Germany) and type. Although eastern German facilities are classified by waste type, it is possible that hazardous and toxic wastes were placed in any of the facilities, given the low level of regulatory oversight there. More than 20 underground facilities are shown on the figure and are generally located in old mines. Most of the other facilities are household waste landfills or landfills for construction and other wastes.

Waste facilities in Germany include two underground repositories located at Herfa-Neurode in Hesse and Zeche Zollverein in North Rhine-Westphalia. The underground waste disposal plant at Herfa-Neurode was established in 1972 by Kali und Salz AG for the underground storage of hazardous wastes. The disposal site is within a potash mine in a 300-m thick salt formation located at approximately 800-m depth. Extraction of the potash was performed using the room and pillar method, leaving "rooms" that can be used for disposal.

According to the operator, numerous categories of waste are stored at the disposal site (Kali und Salz, undated). Wastes include: cyanide; hexachlorinated benzene; arsenic compounds; mercury residues and organic mercury compounds; residues with heavy metals; chemical distillation residues; residues from sewage purification; dye residues; chlorinated solvent residues; waste tar; unusable laboratory chemicals set in concrete; agricultural pesticides; used dry batteries, brake linings, broken fluorescent tubes, old pharmaceuticals; poly chlorinates biphenyls (PCBs)-containing capacitors and drained but still contaminated transformers and incinerator ashes containing salts and possible dioxins. According to the report, no contaminated soil is being deposited in the facility. In addition, no explosive, ignitable, liquid, radioactive, or undefinable mixtures are accepted.



Source: (Umweltbundesamt, 1992)

FIGURE **2-3**

LOCATIONS OF SPECIAL WASTE TREATMENT AND INCINERATION FACILITIES

DOE/ITEP/WA

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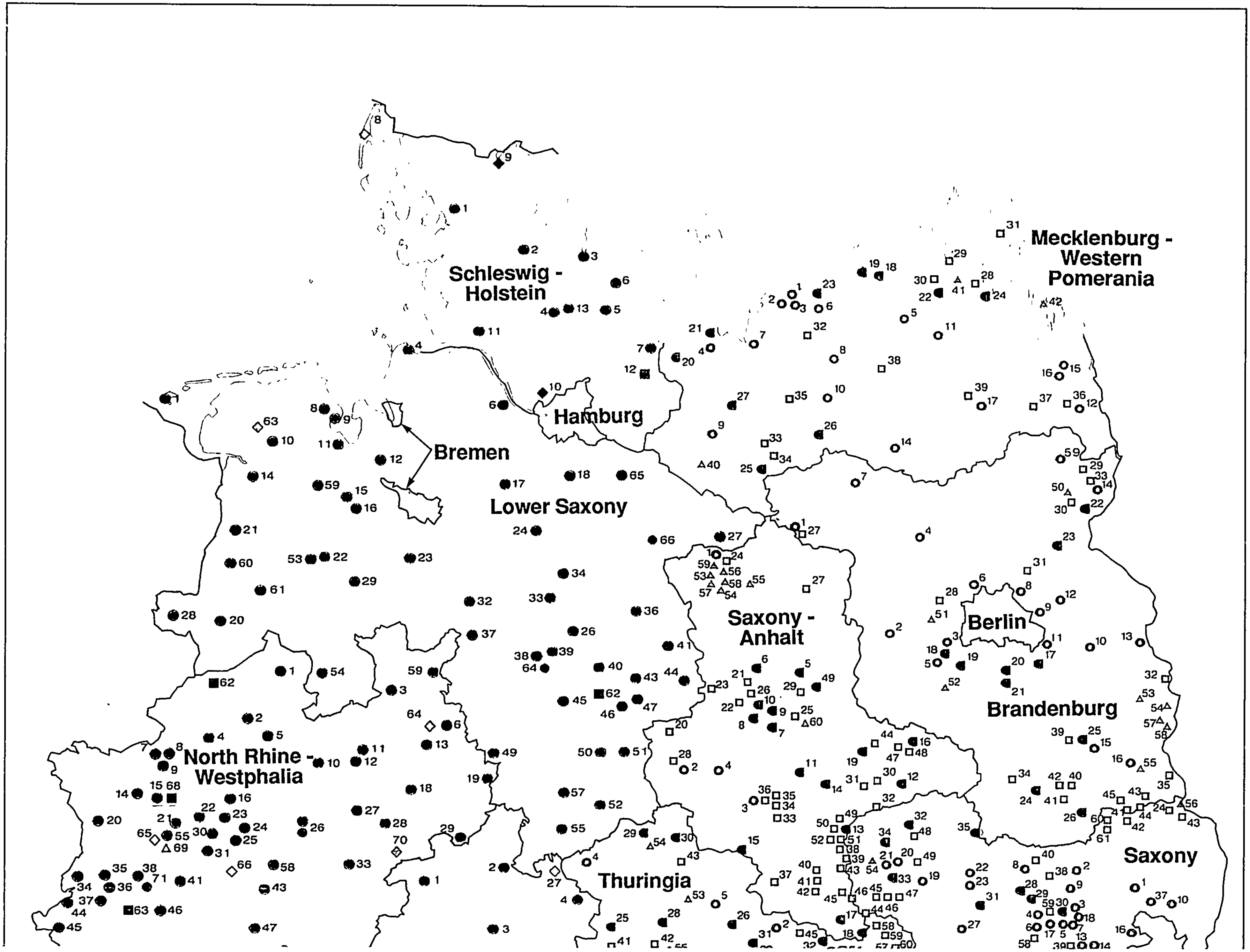
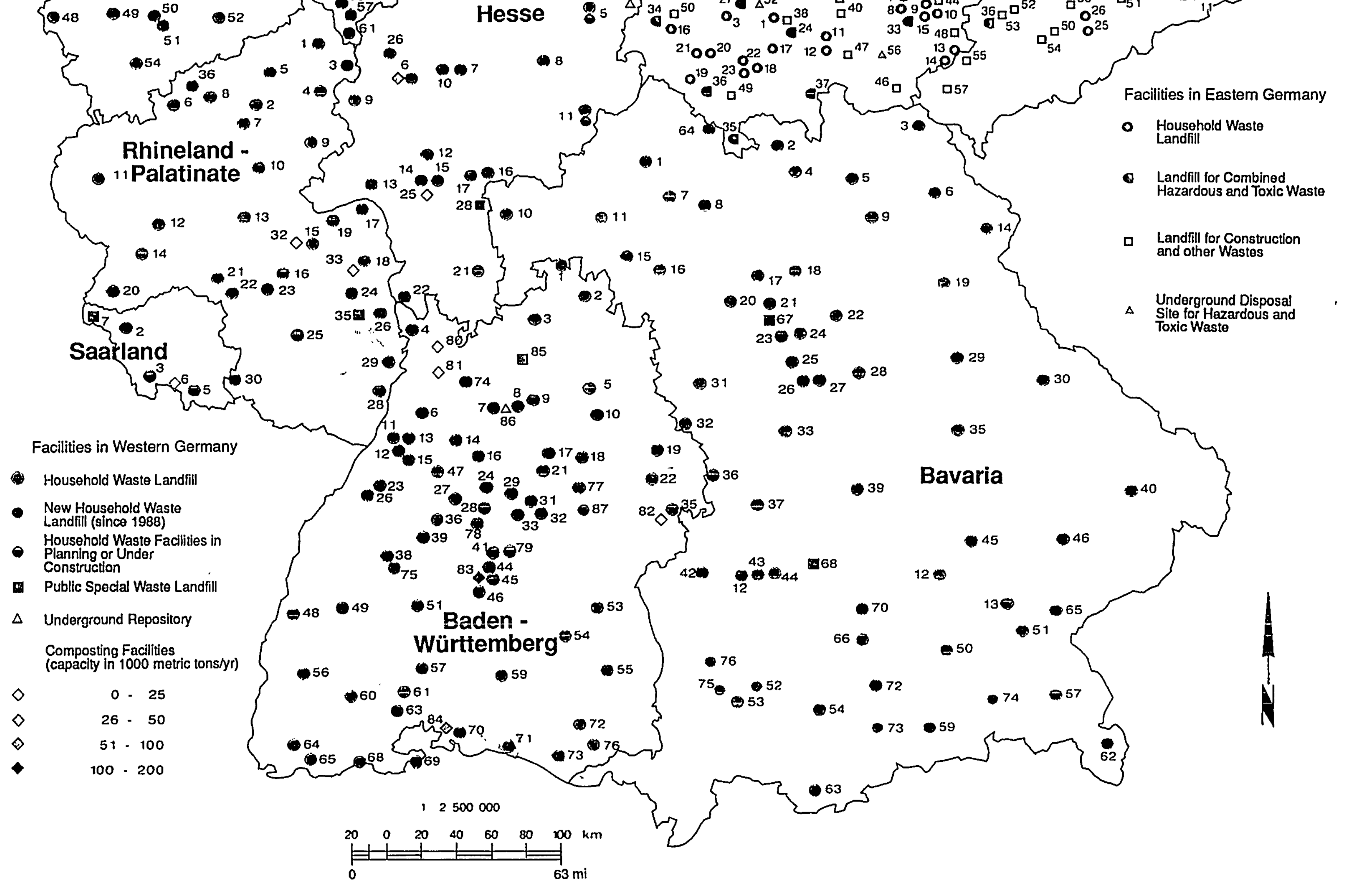

Schleswig - Holstein
Mecklenburg - Western Pomerania
Hamburg
Bremen
Lower Saxony
Berlin
Brandenburg
Saxony - Anhalt
North Rhine - Westphalia
Thuringia
Saxony



Source: (Umweltbundesamt, 1992)

Note: Facility Names Presented in Figure 4-6b.

FIGURE **2-4a**
WASTE DISPOSAL FACILITIES IN GERMANY, 1991
DOE/ITEP/WA

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North Rhine-Westphalia

1 Ibbenbüren II
2 Altenberge
3 Kirchlengern
4 Coesfeld-Höven
5 Münster II
6 Dörentrup
7 Borken-Hoxfeld
8 Altstätte III
9 Bocholt-Lankern III
10 Ennigerloh
11 Westerwiehe II
12 Halle-Künsebeck II
13 Holtsiek
14 Winterswick
15 Hünxe-Schermbeck
16 Datteln-Löringhof
18 Elsen-Warthe
19 Wehrdon
20 Goldorn-Pont
21 Bottrop-Donnersberg
22 Emscherbruch
23 Castrop-Rauxel
24 Huckarde
25 Grevel
26 Werl
27 Erwitte
28 Fröndenberg-Ost-Büren
29 Warburg
30 Kornharpen
31 Hattingen
33 Meschede
34 Brüggen II
35 Viersen II-Nothofer
36 Radermühlenberg
37 Schlibeck
38 Neuss
41 Plöger Steinbruch
43 Lüdenscheid-Kleinleifinghausen
44 Wasserberg-Rothenbach
45 Birgden-Hahnbusch
46 Dormagen Gohr-Broich
47 Leppe
48 Alsdorf-Warden
49 Horm
50 Vereinigte Ville,Hürt
51 Haus Forst
52 St. Augustin Buisdorf
53 Fludersbach
54 Mechernich
55 Oberhausen-Hühnerheide
57 Winterbach
58 Halbeswig
59 Pohlsche Heide
61 Burbach-Würgendorf
62 Ochtrup
63 Grevenbroich-Neuenhausen
64 Lemgo
65 Duisburg
66 Ennepetal
68 Hünxe-Schermbeck
69 Zoche Zollverein
70 Brilon
71 Garzweiler II

Baden-Württemberg

1 Heegwald-Wertheim Dörlesberg
2 Tauberbischofsheim
3 Buchen-Sansheckeh
4 Mannheim-Friesenheimer Insel
5 Kupferzell-Beltersrod
6 Bruchsal
7 Schwaigern-Stetten
8 Heilbronn-Vogelsang
9 Eberstadt
10 Schwäbisch-Hall-Hessental
11 Karlsruhe-Grötzingen
12 Karlsruhe-West
13 Karlsruhe-Ost
14 Maulbronn-Zaiserswelher
15 Karlsbad-Ittersbach
16 Vaihingen/Horrheim
17 Backnang-Steinbach
18 Kaisersbach
19 Ellwangen-Killingen

Hesse

1 Flechtdorf
2 Kirschenplantage
3 Uttershausen
4 Weidenhausen
5 Am Mittrück
6 Aßlar
7 Reiskirchen
8 Bastwald
9 Beselch
10 Allendorf
11 Kalbach
12 Brandholz
13 Dyckerhoffbruch
14 Wicker
15 Buchschlag
16 Haller
17 Hohenzell
21 ZD Odenwald (Brombachtal)
22 Lampertheimer Wald
24 Herfa-Neurode
25 Bischofsheim
26 Scheiderwald
27 Witzenhausen
28 Mainhausen (geplant)

Schleswig-Holstein

1 Ahrenshöft
2 Alt Duvenstedt
3 Schönwohldt
4 Ehndorf
5 Damsdorf
6 Rastorfer Kreuz
7 Niemark
8 Westerland
9 Flensburg
10 Pinneberg
11 Ecklak-Kanalstrich
12 Rondeshagen
13 Neumünster Wittorferfeld

Bavaria

1 Arnshausen
2 Blumenrod
3 Hof am Silberberg
4 Oberlangheim
5 Höferänger
6 Sandmühle
7 Rothmühle
8 Wonfurt
9 Heinersgrund
10 Stockstadt
11 Karlstadt
12 Haag-Marchenbach
13 Haag-Schachenwald
14 Steinmühle
16 Nenzenheim
17 Modbach
18 Gosberg
19 Mantel-Kalkhäusl
20 Diespeck
21 Herzogenaurach
22 Neunkirchen a.S.
23 Fürth-Atzenhof
24 Nürnberg-Süd
25 Schwabach Neuses
26 Georgensgmünd
27 Pyras
28 Neumarkt-Blomenhof
30 Sengenbühl
31 Aurach
32 Kreismülldeponie Guggenberg
33 Cronheim
35 Posthof
36 Nördlingen
37 Binsberg
39 Starkertshofen

Lower Saxony

1 Borkum
4 Cuxhaven
6 Katzendorf II
8 Wiefels
9 Wilhelmshaven Nord
10 Großefehn
11 Varel Hohenberge
12 Brake Mitte
14 Breinermoor
15 Oldenburg/Osternburg
16 Bargloy
17 Helvesiek-Rehr
18 Dibbersen
20 Venneberg
21 Dörpen
22 Sedelsberg
23 Bassum
24 Hillern
26 Kolenfeld
27 Woltersdorf
28 Wiesum II
29 Tonnenmoor
32 Nienburg
33 Wietze
34 Offen
36 Wesendorf
37 Rehburg-Loccum
38 Hannover
39 Burgdorf
40 Stedum
41 Wolfsburg-Fallersleben
43 Watenbüttel
44 Süpplingenburg
45 Heinde
46 Gebhardshagen
47 Bornum
49 Polle
50 Bornhausen
51 Morgenstern
52 Hattorf
53 Stapelfeld
54 Piesberg
55 Deiderode
57 Blankenhagen
59 Mansie
60 Wesuwe
61 Flechum
62 Hohenegqelsen
63 Aurich
65 Lüneburg-Bardowick
66 Berg

Saarland

2 Merzig-Fitten (Hilbringen)
3 Lisdorf
5 Ormesheim
6 Saarbrücken
7 Eft-Hellendorf (geplant)

Rhineland-Palatinate

1 Nauroth
2 Linkenbach
3 Rennerod
4 Meudt-Beckershald
5 Neustadt (Wied) Femtal
7 Ochtendung-Eiterköpfe
8 Brohl-Lützing
9 Singhofen
10 Gondershausen
11 Plütscheid
12 Sohlém
13 Kirchberg-Unzenberg
14 Mertesdorf
15 Langenlonsheim
16 Meisenheim-Callbach
17 Budenheim

Mecklenburg-Western Pomerania

1 Schmadebeck
2 Zweendorf
3 Parkentin
4 Degtow
5 Rönkendorf
6 Darkow
7 Möggenburg
8 Glasewitz
9 Kloddram
10 Goldberg
11 Utzedel/Dorotheenhof
12 Pasewalk (SMD)
14 Wildkuhl
15 Mimersdorf
16 Blumenthal
17 Neubrandenburg-Lindenhof
18 Camitz
19 Körkwitz
20 Schönberg
21 Tarnowitz (MD)
22 Grimmen, Kaschower Werder
23 Diedrichshagen (GD)
24 Greifswald (MD/Alte Dep.)
25 Wanzitz
26 Paarsch
27 Stralendorf
28 Ladebow (Havariedeponie)
29 Neuhof
30 öldeponie GM 26
31 Lancken-Saßnitz
32 Langen-Trechow
33 Neustadt-Glewe (Ind.müllhalde)
34 Neustadt-Glewe (Fettdeponie)
35 Göhren (Havariefläche)
36 Brölin
37 Adolfsdeck
38 Klein Wokern
39 Magdalenenhöhe (Aschod.)
40 Lübtheen, Schluckbohrung 1
41 Reinkenhagen, S 52/102
42 Lütow, S 1,6,35

Brandenburg

1 Wittenberge
2 Brandenburg-Fohrde
3 Doetz
4 Krangen
5 Golm
6 Germendorf
7 Scharfenberg, Wittstock
8 Schwanebeck-Nord
9 Neuenhagen
10 Fürstenwalde-Langewahl
11 Wernsdorf
12 Hennickendorf
13 Boossen-Seefichten
14 Schwedt
15 Ratsvorwerk (GMD)
16 Cottbus-Saspow
17 Senzig
18 Vorketzin
19 Fresdorfer Heide/Tremsdorf
20 "Schöneicher Plan"
21 Schöneiche (SMD)
22 Pinnow-Dobberzin
23 Eberswalde-Ostende
24 Hennersdorf
25 Lübben
26 Senftenberg-West u. Havarieverk.
27 Wittenberge (Ind.müllhalde)
28 Rötheholf-Neu Fahrland
29 Zichow "Große Hölle"
30 Welsow "Töpferberge"
31 Albertshof
32 Schlammhalde
33 Grabentanks
34 Tröbitz
35 Groß Kölzig
39 Lübben
40 Annahütte RL 7
41 Pflugkippe 7
42 Annahütte RL (PB-Neutraschlamm)
43 Teerkippe-Friedrichshain
44 Friedrichshain (Phenolwasserversp.)

Thuringia

1 Stadtilm
2 Apolda-Küchelgrube
3 Tambach-Dietharz
4 Udor/Leuterode
5 Michelshöhe
6 Untitz
7 Münchenbernsdorf
8 Kleinbernsdorf
9 Großeutersdorf
10 Großlöbichau/Schillertal (SMD)
11 Debragraben
12 "Herbstdelle"
13 Weißendorf
14 Greiz/Gommla
15 Lärchenberg, Gera-Langenb. (ehem. SST
16 Bad Salzungen, Kloster
17 Ilmenau/Büchelch
18 Schmiedefeld
19 Kaltensundheim
20 Trusetal
21 Niederschmalkalden
22 Goßenhöhen
23 Suhl-Goldlauter
24 Rehestädt
25 Buchenau
26 Schwerborn
27 Gotha-Ostfeld
28 Bad Langensalza "Kalkberg"
29 Beinrode
30 Nenzelsrode
31 Süßenborn
32 Tongr. Königshofen (MD)
33 Erdmannsdorf
34 Hedwigsgraben-Vacha (SMD)
35 Lolmrioth
36 Meiningen, Töngraben
37 Mengersgereuth-Hämmern
38 Rehestädt
39 Oberlim
40 Oberlim (Saline, Aschehalde)
41 Horschlitt
42 Laucha
43 Jecha/Sondershausen
44 Wünschendorf
45 Dornburg
46 Remtendorf
47 Maxhütte
48 Großkundorf/Trünzig, Becken A
49 Themar
50 Möhra
51 AGA (Gifte u. Schadstoffe)
52 Neudietendorf S III)
53 Kirchheiligen S 18)
54 Schachtanlage Hain I)
55 Rockensussra S 5)
56 Schacht "W.U."
57 Hainichen
58 Wintersdorf
59 TRL "Neue Sorge"
60 TRL "Phönix Ost" Rositz

Saxony

1 Göda-Buscheritz
2 Neuendorf
3 Klein Luga
4 Cossebaude
5 BW-Rossendorf
6 Gompitz
7 Z/K Rossendorf (Beir.gel)
8 Basslitz
9 Bischheim-Häslich
10 Großschweidnitz
11 Leupoldishain
12 Pirna
13 Pirna-Zehista
14 Kleincotta
15 Riesa
16 Sebnitz
17 Dresden, Cunnersdorfer Str.
18 Dresden-W., Weißing-Str.
19 Grimma-Rumberg
20 Holzhausen
21 Geschwitz
22 Lüttnitz (Oschatz)
23 Zöschau

22 Essingen-Ellert
23 Gaggenau-Oberweier
24 Leonberg-Rübenloch
26 Baden-Baden
27 Simmozheim
28 Sindelfingen-Dachsklinge
29 Stuttgart-Hedelfingen
31 Esslingen-Katzenbühl
32 Nürtingen-Blumentobel
33 Filderstadt-Ramsklinge
35 Nattheim
36 Neubulach-Oberhaugstett
38 Bengelbruck-Baiersbronn
39 Altensteig-Walddorf
41 Tübingen-Schweinerain
44 Dußlingen
45 Mössingen
46 Hechingen
47 Hohberg-Pforzheim
48 Ringsheim-Kahlenberg
49 Haslach
51 Oberndorf-Bochingen
53 Iltzholz-Ehingen
54 Unlingen-Riedlingen
55 Ochsenhausen-Rheinstetten
56 Freiburg-Eichelbuck
57 Tuningen
59 Ringgenbach
60 Titisee-Neustadt
61 Hüfingen
63 Wutach-Münchingen
64 Wieslet
65 Wehr-Lachengraben
68 Tiengen
69 Lottstetten
70 Singen-Rickelshausen
71 Konstanz-Bottenberg
72 Ravensburg-Gutenfurt
73 Weiherberg-Friedrichshafen
74 Sinsheim-Saugrund
75 Horb-Rexingen
76 Wangen-Obermooweiler
77 Schorndorf
78 Böblingen-Oberer Kerferhau
79 Reutlingen-Schinderteich
80 Heidelberg-Feilheck
81 Wiesloch
82 Heidenheim
83 Dußlingen
84 Singen
85 Billigheim
86 Salzbergwerk Heilbronn

42 Burgau
43 Augsburg-Gersthofen
44 Gallenbach
45 Oberglaim
46 Asbach-Maigorsdorf
50 Ebersberg-Schafweide
51 Sollacher Forst
52 Oberostendorf
53 Kaufbeuren
54 Erbenschwang
57 Litzlwalchen
59 Hausham
62 Bischofswiesen-Winkl
63 Schwaiganger
64 Herbstadt
65 Eisenfelden
66 Müncherl-Nord-West
67 Raindorf
68 Gallenbach
70 Jedenhofen
72 Greiling - Am Vorberg
74 Sieghart
75 Hegnenbach
76 Breitenbrunn

19 Sprendlingen
20 Saarburg
21 Reichenbach
22 Gutsbezirk Baumholder
23 Schneeweiderhof
24 Eisenberg
25 Kaiserslautern-Kapiteltal
26 Haßheim
28 Berg
29 Speyer
30 Zweibrücken-Rechenbachtal
32 Bad Kreuznach
33 Alzey
35 Gerolsheim
36 Ödingen

49 Pietzpuhl
50 Mittenwalde, Kaverne
51 Ketzin, Sonde
52 Buchholz, Inj.sonde UGB2P27
53 Trebatsch, Bohrung 1
54 Wellmitz, Bohrung 3
55 Lakoma S 6
56 Döbern S 6
57 Guben S 27
58 Guben S 44 (Betr.deponie)

59 Mlmersdorf (SMD)

Saxony-Anhalt

1 Chüttlitz
2 Wernigerode
3 Hettstedt
4 Westerhausen
5 Burg (Siedlungsabf.)
6 Vahldorf (SMD)
7 Frohser Berge
8 Blumenberg
9 Mgb. Cracauer Anger
10 Hängelsberge (Siedlungsabf.)
12 Golpa I, Zschornewitz
13 Lochau Großdeponie
14 Köthen, Scherbelberg (MD)
15 Edersleben "Hutdockel"
16 Reinsdorf-Doblen
17 Luckenau
18 Nissma (MD)
19 Dessau Kochst. Kreisstr.
20 Osterwieck
21 Emden (HCH-Deponie)
23 Grube "Hoffnung", Barneberg-IAL7745
24 Liesten
25 Schönebeck (Neutraschlamm)
26 Unseburg (MD)
27 Beesewege
28 Vitholz
29 Ladeburg (Hav.fl., Brandpl.)
30 Grube "Antonie" BII/III
31 TRL Freiheit IV (Spülkippe)
32 TRL Freiheit III (Spülkippe)
33 Halde-W-S-Schacht (Theisenschlamm)
34 Halde Niewandtschacht, Siersl/FL V5
35 Halde-N-W-Schacht, SL/FL 2
36 Halde-N-W-Schacht, SL/FL 6
37 Karlsdorf RL 1
38 Buna IAA
39 Buna Trockenkippe
40 Hochhalde LEUNA (ZW.d.Nord)
41 Hochhalde LEUNA (südl.Erw.)
42 TRL Großkayna
43 TRL Braunsbedra, IAA
44 Grube "Berta"
45 TRL "Oberabtei", Webau
46 Halde Gerstewitz
47 Halde Griebow/Apol. (Schutt, Rückst.)
48 Plesteritz, IAA (Schlammdeponie)
49 Lochau-Gleisdeponie
50 Lochau-Großdeponie
51 Lochau-SD I
52 Lochau-SD II
53 Peckensen S I
54 Verpreßsonde UGLT 10V72
55 Objekt Brüchau (Dep. u. Sonde)
56 Gehrstedt S I
57 Gehrstedt S II
58 Gehrstedt S III
59 Gehrstedt S 80
60 Schönebeck Kaverne (DCP)

25 Griessbach
26 Börnichen
27 Wiesenburg ("Lohe")
28 Meißen
29 Halde Gröbern
30 Dresden-Hammerweg (Sickerbeete)
31 Hohenlauft
32 Zschepplin (südl.)
33 Liebertwolkwitz
34 Seehausen
35 Belgern (Ind dep.)
36 Dänkritz
37 Bautzen
38 Dallwitz
39 Pirna
40 Nünchritz
41 Teerölfeststoffbecken 11 u. 12
42 Teerölfeststoffbecken 4,5 u. 6
43 "Philippine"
44 TRL Rusendorf/Mumsdorf
45 Neue Aschekippe Böhlen
46 Espenhain, LKW-Kippe (MD)
47 Trages, IAA
48 Eilenburg (Trockendeponie)
49 Reinhild-Süd, Brandis
50 Neukirchen/Klaffenb. (Säureharz)
51 ZUG, Alte Ziegelei
52 Glauchau, Schafteich
53 Schafteichgelände
54 Niederwürschnitz RL5
55 Limbach (Schlammdeponie)
56 Chemnitz-Weißer Weg "Neuendorfer Delle
57 Plauen (Glaubers u. Zelluloseabf.)
58 Havariedeponie Maxen
59 Reichsbahndeponie
60 RL Halde (Rotschlammversp.)
61 ZWL Vanadinrohsalz

FIGURE **2-4b**

LISTING OF WASTE DISPOSAL FACILITIES IN GERMANY, 1991

DOE/ITEP/WA

Source: (Umweltbundesamt, 1992)

PROJECT NO. 913-1248.500 DRAWING NO. 43907 DATE 8/24/92 DRAWN BY TK

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Waste is secured in the facility by the following mechanisms:

- Packing — Fireproof, tightly sealed, chemically and mechanically stable containers are used, and in special cases the concrete or other additional isolation material may be used.

- Walling up — Following filling of a room, a brick wall is constructed that completely surrounds the stored wastes and separates them from other mining rooms.

- Damming up of storage fields — Storage fields include cavities for approximately five years' storage time, which are hermetically sealed with two brick walls separated by a distance of 5-to 6-m, with the space filled tight with anhydride concrete.

- Shaft filling — When waste disposal at Herfa-Neurode is completed, plans call for filling of the shafts with low-permeability substances.

Waste samples are collected from each waste consignment to confirm and verify waste composition. These samples are permanently stored in a special storage area as a physical record of stored wastes. The estimated capacity of Herfa-Neurode is currently 20 additional years. However, potash mining in adjacent areas is creating cavities that may also become part of the waste disposal facility.

More treatment and disposal facilities, including underground disposal sites, are considered necessary by the German government to handle wastes produced during cleanup of eastern German sites. The government is investigating potential use of former potash mines in the eastern German states of Saxony-Anhalt and Thuringia as underground disposal sites for special wastes (Haznews, 1991c). It is expected that these sites would be operated in a manner similar to Herfa-Neurode.

German officials have documented an increase in illegal exports of hazardous waste, which is due to a lack of facilities and the high cost of treatment and disposal. Crimes related to the illegal disposal of waste were up by 19.2% in 1991 (Haznews, 1992d). Legal treatment and disposal costs are between DM 1,000-6,000 per metric ton, compared to as little as DM 5-10 per metric ton for illegal disposal, according to the Federal Environment Agency in Berlin.

All radioactive waste in Germany is placed in temporary storage facilities at this time. The responsibility of radioactive waste conditioning and interim storage is placed on the producer until the waste can be transported to a state-operated collection center or federal disposal facility. All costs are borne by the producer through direct conduct of the work or through payment to a fund which supports work conducted by the government. High-level liquid waste conditioning and immobilization have been under development in Germany for many years. Currently, all high-level waste in Germany is generated and stored at the WAK pilot-scale reprocessing plant.

Two deep geologic repository sites are under investigation in western Germany for radioactive waste disposal. The Konrad site is located in an abandoned iron mine in Lower Saxony. Plans call for a repository there to begin receiving waste in 1994. The Gorleben site is within a large salt dome in Lower Saxony and has been nominated as the location for a high-level waste repository. Underground exploration at the site is expected to be completed between 1995 and 1999.

German planning calls for all non-heat-generating intermediate- and low-level wastes to be disposed of in the Konrad repository. Prior to disposal, wastes will be conditioned by a variety of methods, including evaporation, filtration, compaction, incineration, bituminization, and solidification in cement. Treatment is generally performed on-site, often with portable equipment.

All high-level radioactive waste, including non-standard spent fuel elements, vitrified high-level waste, and other heat-producing wastes, will be considered for disposal at the Gorleben repository. Spent fuel rods will be consolidated and encapsulated in casks prior to disposal. Vitrified high-level waste being returned from foreign reprocessing plants will also be deposited at the Gorleben repository site.

Prior to unification, a low- and intermediate-level nuclear waste repository was in operation in Morsleben, Saxony-Anhalt within an abandoned potash and salt mine. Three main types of final disposal were performed: (1) conventional handling and stacking of drums; (2) dumping of intermediate-level solid radioactive waste by means of a contamination lock above the solid waste disposal cavern; and (3) in situ solidification of liquid waste. Each method was carried out in separate caverns in the salt approximately 500-m below ground (Nuclear Engineering International, 1990). The repository was operated from 1972 to 1990, but operation has since been halted to permit evaluation.

All spent fuel elements in eastern Germany were transported to the former Soviet Union for reprocessing and subsequent disposal. No other high-level waste was reportedly generated or disposed of in eastern Germany.

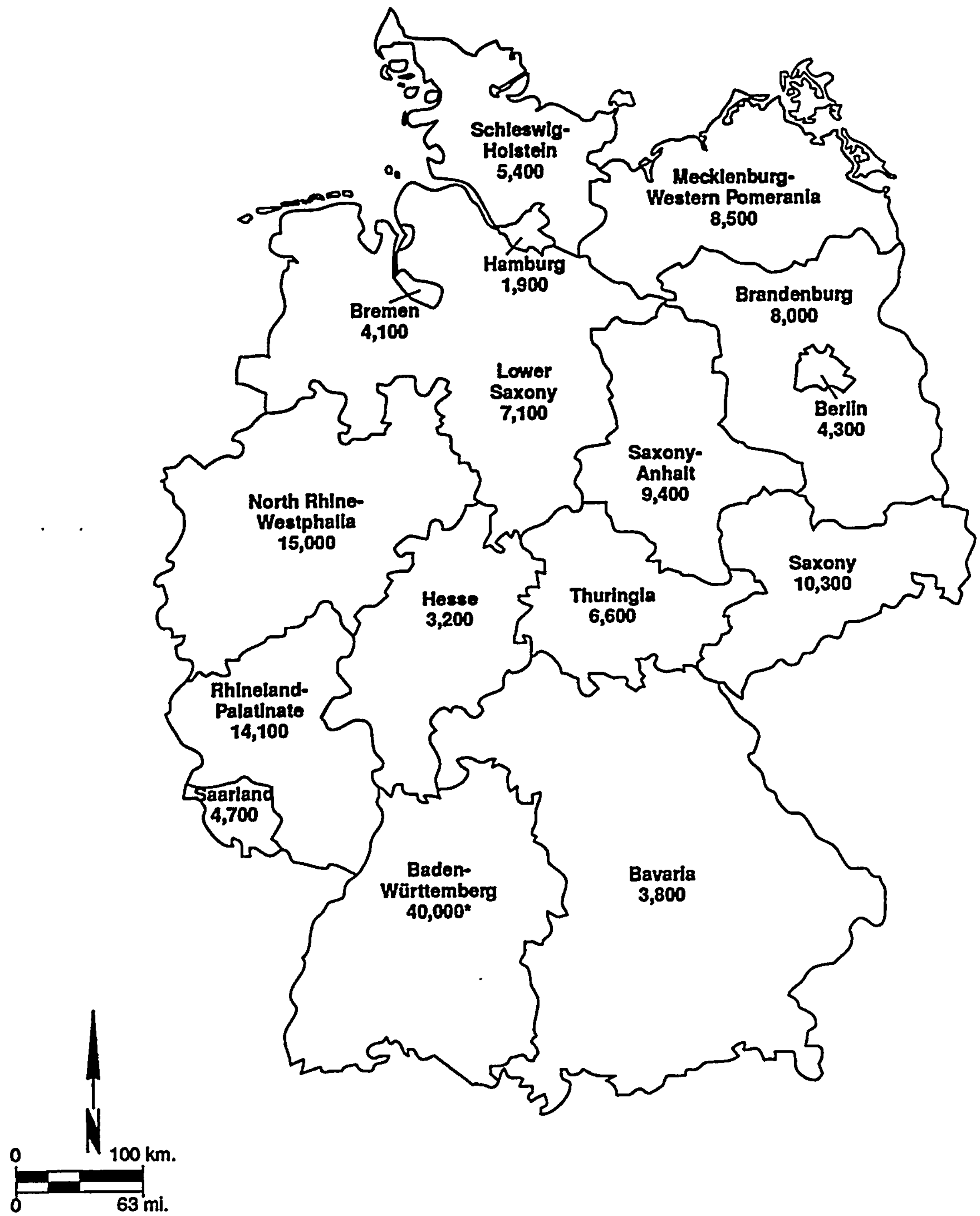
2-2 Specific Contaminated Problems in Germany

The scale of environmental damage and associated costs and health effects are uncertain in Germany. Estimates of the number of contaminated sites are presented in this chapter, followed by a discussion of specific contamination problems in Germany with emphasis on soil, groundwater, and river system contamination.

2-2-1 Estimated Number of Contaminated Sites

According to Heinrich Freiherr, President of the Federal Ministry for the Environment, monitoring and registration of suspected contaminated sites is difficult because of the lack of a national approach to contaminated site registration (Haznews, 1991e). Steps are being taken to improve estimates and registration of sites. The German government is planning a "contaminated site center" that will be responsible for collecting and managing contaminated site data and for coordination of cleanup measures (Haznews, 1991d).

Estimates of the number of suspected contaminated sites in Germany have been increasing as additional studies are performed. In 1983, the Federal Environment Agency estimated 28,000 potential hazardous sites existed in West Germany. In 1985 and 1987, the estimates increased to 35,000 and 42,000, respectively (Jessberger, 1992). By 1989, 48,000 potential hazardous sites were recorded in West Germany (BMFT, 1991a). Following unification, an estimate as of October 1991 by the Federal Environmental Agency, indicated that 146,400 suspected contaminated sites exist in Germany, including 99,300 sites in western Germany and 47,100 sites in eastern Germany. Further predictions by the Federal Environmental Agency suggest that 180,000 sites will be identified when surveys are complete. Of these, an estimated 10 to 20% will require remediation to reduce public health risks to acceptable levels, resulting in an estimated 18,000 to 36,000 sites in Germany potentially requiring some form of remediation (Jessberger, 1992). Individual state estimates of suspected contaminated sites are shown in Figure 2-5. A breakdown of the types of contaminated sites by region or state is presented in Table 2-2.



* Reported to be a high estimate

Source: (Jessberger, 1992)

FIGURE **2-5**

SUSPECTED CONTAMINATED SITES IN GERMAN STATES (OCTOBER 1991)

DOE/ITEP/WA

PROJECT NO. 913 1248.500 DRAWING NO. 43785 DATE 10/1/92 DRAWN BY TB

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Table 2-2. ESTIMATES OF SUSPECTED CONTAMINATED SITES IN GERMANY

State/Region	Estimate	Reference
Germany	146,400 suspected contaminated sites	(Jessberger, 1992)
Eastern Germany	47,100 suspected contaminated sites	(Jessberger, 1992)
Eastern Germany	27,700 suspected contaminated sites	(Haznews, 1991e)
Eastern Germany	11,000 waste disposal sites	(Haznews, 1991e)
Eastern Germany	15,000 industrial waste sites	(Haznews, 1991e)
Eastern Germany	700 military sites	(Haznews, 1991e)
Eastern Germany	1,000 "areas of wide contamination"	(Haznews, 1991e)
Eastern Germany	15,000 controlled and uncontrolled landfills	(Haznews, 1991c)
Eastern Germany	14,000-20,000 contaminated sites	(Haznews, 1991b)
Eastern Germany	13,000 uncontrolled landfills	(Haznews, 1991a)
Eastern Germany	40,000 possible contaminated sites	(US Dept. of Commerce, 1992)
Eastern Germany	28,000 known contaminated sites	(US Dept. of Commerce, 1992)
Western Germany	99,300 suspected contaminated sites	(Jessberger, 1992)
Western Germany	5,000-7,500 contaminated sites	(Haznews, 1991a)
Baden-Württenberg	40,000 suspected contaminated sites	(Jessberger, 1992)
Baden-Württenberg	6,500 waste disposal sites	(Haznews, 1991b)
Bavaria	3,800 suspected contaminated sites	(Jessberger, 1992)
Bavaria	482 waste disposal sites	(Haznews, 1991b)
Bavaria	73 industrial waste sites	(Haznews, 1991b)
Berlin	4,300 suspected contaminated sites	(Jessberger, 1992)
Berlin	332 waste disposal sites	(Haznews, 1991b)
Berlin	1,593 industrial waste sites	(Haznews, 1991b)
Brandenburg	8,000 suspected contaminated sites	(Jessberger, 1992)
Bremen	4,100 suspected contaminated sites	(Jessberger, 1992)

Table 2-2. (Cont.) ESTIMATES OF SUSPECTED CONTAMINATED SITES IN GERMANY

State/Region	Estimate	Reference
Bremen	74 waste disposal sites	(Haznews, 1991b)
Bremen	169 industrial waste sites	(Haznews, 1991b)
Hamburg	1,900 suspected contaminated sites	(Jessberger, 1992)
Hamburg	1,550 waste disposal sites	(Haznews, 1991b)
Hamburg	290 industrial waste sites	(Haznews, 1991b)
Hesse	3,200 suspected contaminated sites	(Jessberger, 1992)
Hesse	5,123 waste disposal sites	(Haznews, 1991b)
Hesse	61 industrial waste sites	(Haznews, 1991b)
Lower Saxony	7,100 suspected contaminated sites	(Jessberger, 1992)
Mecklenburg-West. Pomerania	8,500 suspected contaminated sites	(Jessberger, 1992)
Mecklenburg-West. Pomerania	1,000 disposal sites	(Haznews, 1991e)
Mecklenburg-West. Pomerania	2,400 industrial sites	(Haznews, 1991e)
Mecklenburg-West. Pomerania	110 military sites	(Haznews, 1991e)
Mecklenburg-West. Pomerania	6,200 waste disposal sites	(Haznews, 1991b)
Mecklenburg-West. Pomerania	223 potentially contaminated munitions sites	(Haznews, 1992a)
North Rhine-Westphalia	15,000 suspected contaminated sites	(Jessberger, 1992)
North Rhine-Westphalia	8,639 waste disposal sites	(Haznews, 1991b)
North Rhine-Westphalia	3,807 industrial waste disposal sites	(Haznews, 1991b)
Rhineland-Palatinate	14,100 suspected contaminated sites	(Jessberger, 1992)
Rhineland-Palatinate	7,528 waste disposal sites	(Haznews, 1991b)
Saarland	4,700 suspected contaminated sites	(Jessberger, 1992)
Saarland	1,728 waste disposal sites	(Haznews, 1991b)
Saarland	1,868 industrial waste sites	(Haznews, 1991b)

Table 2-2. (Cont.) ESTIMATES OF SUSPECTED CONTAMINATED SITES IN GERMANY

State/Region	Estimate	Reference
Saxony	10,300 suspected contaminated sites	(Jessberger, 1992)
Saxony-Anhalt	9,400 suspected contaminated sites	(Jessberger, 1992)
Saxony-Anhalt	352 WWII munition sites	(Haznews, 1991e)
Schleswig-Holstein	5,400 suspected contaminated sites	(Jessberger, 1992)
Schleswig-Holstein	2,538 waste disposal sites	(Haznews, 1991b)
Schleswig-Holstein	2,500 disposal sites	(Haznews, 1991e)
Thuringia	6,600 suspected contaminated sites	(Jessberger, 1992)

Additional information on the distribution of suspected contaminated sites by type is available for eastern Germany. According to a study conducted by the Institut für Wirtshaftsforschung, a German economic forecasting institute, there are an estimated 27,700 suspected contaminated sites in eastern Germany, consisting of approximately 11,000 waste dumps, 15,000 industrial sites, 700 armament sites, and 1,000 areas of extensive ground contamination. This information is presented for each eastern German state in Figure 2-6. Of the total estimated number, approximately 2,500 have been confirmed as contaminated, including approximately 1,100 waste dumps, 1,300 industrial sites, 40 armament sites, and 60 areas of extensive ground contamination. The study did not include former Soviet army sites, radioactive contamination sites, or agricultural soil contamination. Total remediation costs for the sites were estimated in the study to be DM 211,500-million (Haznews, 1991e).

2-2-2 Examples of Contaminated Sites

A review of 15 contaminated sites within Germany is presented in Appendix A to illustrate the extent and nature of hazardous waste cleanup problems in Germany. The descriptions include some of the more severe problems to be addressed. Sites included in Appendix A are: Georgswerder Landfill, Hamburg; Müggenburgerstraße Landfill, Hamburg; Altwarmbüchen Landfill, Lower Saxony; Münchenhagen Landfill, Lower Saxony; Grube Merkel/Gifhorn, Lower Saxony; Bielefeld-Brake Landfill, North Rhine-Westphalia; Prael Landfill, Rhineland-Palatinate; Hirschhagen, Hesse; Malsch Landfill, Baden-Württemberg; Marktredwitz, Bavaria; Schönburg Landfill, Mecklenburg-Western Pomerania; Deponie Antonie, Saxony-Anhalt; Heideloh, Saxony-Anhalt; Wismut AG, Thuringia and Saxony; and Firma Oel Pintsch Gmbh., Berlin.

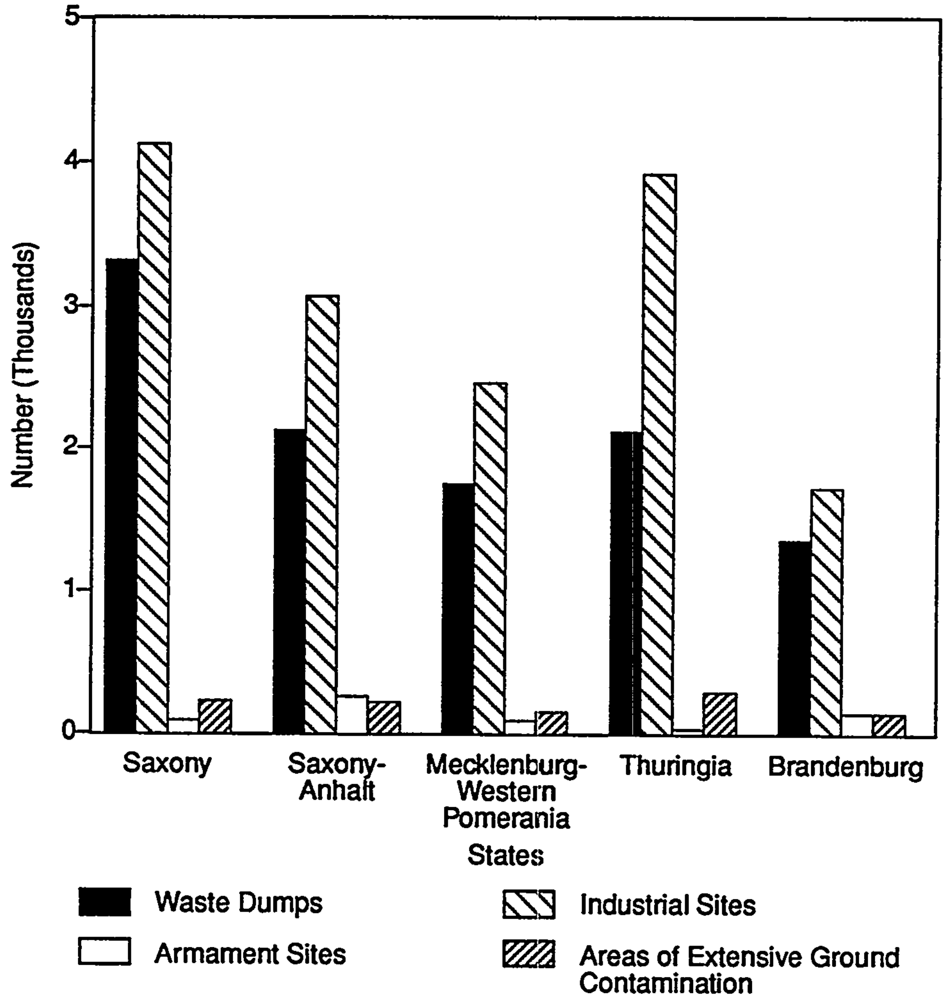
2-2-3 Soil and Groundwater Contamination Susceptibility

Groundwater is the primary water source in Germany, accounting for approximately 85% of the water supply. The following overview illustrates the regional variability of groundwater resources and general susceptibility to subsurface contamination within Germany.

The geological formations in Germany can be classified into four general units based on age:

- Cambrian through Carboniferous age, strongly deformed, intrusive igneous and metamorphic units;
- Permian through Tertiary age, moderately deformed, sedimentary and extrusive igneous units;
- Tertiary molasse deposits adjacent to the Alps; and
- Quaternary glacial deposits.

The oldest unit consists of rocks from Cambrian to Carboniferous age. These rocks are heavily folded and faulted, with large sections significantly metamorphosed. Plutonic rocks have intruded the sediments in many areas. This group of rocks outcrop in various regions of Germany, including the Harz Mountains, the Rhine Massif, the Black Forest, and the Frankenwald (Ziegler, 1982; Lüttig et al., 1980). The rocks of this unit are characterized by very low permeabilities, and groundwater resources are generally limited to low-yield wells producing from fracture zones. Groundwater in these zones may be highly susceptible to contamination, if releases to fracture zones occur.



Source: (Bundesministerium für Umwelt, 1990)

FIGURE **2-6**

TYPES OF SUSPECTED CONTAMINATED SITES IN EASTERN GERMANY

DOE/ITEP/WA

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The Permian to Tertiary age group overlies older rocks at an unconformity and is composed primarily of sedimentary rocks. This unit has been subjected to the Saxonian orogeny, an event of moderate strength in the Tertiary causing broad folding and uplift of moderate elevation mountain ranges, such as the Harz Mountains. During this time, vast thicknesses of limestone were deposited, as well as sandstones, siltstones, and shales. Other lithological units include Permian salt deposits, basalts and other volcanic rocks deposited at various times throughout the period, and coal beds deposited during the Upper Carboniferous in the Ruhr region. Since deposition, Permian salts have formed diapirs (salt domes), which are one of the main oil trap structures in northern Germany. The Permian through Tertiary aged rocks are widely exposed throughout Germany in areas which extend from Hannover southward to approximately Stuttgart, Augsburg, and Ingolstadt, and to the west as far as Dortmund. Throughout much of central and southern Germany, these deposits are highly permeable, producing extensive and very productive aquifer systems consisting of highly jointed and "karstified" limestone and dolomite deposits. Large deposits of quartzose sandstones throughout central Germany and fractured basalts in the Vogelsburg region are also highly permeable. Local regions of lower permeability clays, silts, and sands are interspersed within the more permeable deposits (Ziegler, 1982; Lüttig et al., 1980). Groundwater supplies in these units are generally expected to be highly susceptible to contamination, unless low permeability clays with limited fracturing are present near the surface to provide a barrier to contaminants.

From the Alps northward through the München and Augsburg area, Tertiary molasse deposits are present, consisting of sedimentary units including conglomerates, sandstones, and shales associated with uplift of the Alps in the Tertiary (Ziegler, 1982; Lüttig et al., 1980). The permeability of the molasse deposits generally ranges from very low to moderate with good production found only in localized aquifers. Contaminant susceptibility of these aquifers is variable, depending on the presence of a low permeability unit between the ground surface and the aquifer. Unconfined aquifers in this formation are considered highly susceptible to contamination.

Quaternary glacial and other unconsolidated sediments are exposed from the northern boundaries to as far south as Hannover in western Germany and Dresden in eastern Germany. These deposits are generally composed of flat-lying Tertiary and Quaternary fluvial and glaciofluvial deposits overlying the gently folded or dipping Permian through Tertiary units. The glacial deposits are often sandy and consequently relatively high permeability materials. However, certain units have a high clay content and may provide a low permeability barrier to contamination, provided significant fracturing or desiccation is not present.

Considerable Quaternary glacial moraine deposits extend north of München off the northern flanks of the Alps. Most of the morainal deposits are of low to very low permeability with localized zones of moderate permeability and susceptibility to contamination. More productive and permeable aquifers consisting of gravels and sands exist along the flanks of the many rivers draining the Alps as well as within the Rhine Graben. In many areas of Germany, artificial recharge work is performed within these highly permeable river valley deposits, drawing river water through the ground into a system of extraction wells. The river valley deposits are highly susceptible to contamination, because of high permeabilities and groundwater velocities (Wilderer et al., 1985). Artesian conditions are found in the localized areas along river valleys to the north and east of München.

Figure 2-7 presents a generalized hydrogeologic map of Germany. Additional information on surficial geology in eastern Germany is presented in Figure 2-8.

2-2-4 Groundwater Quality

Chemical releases to the environment have caused widespread groundwater contamination in Germany. According to the Federal Ministry for the Environment, groundwater quality has

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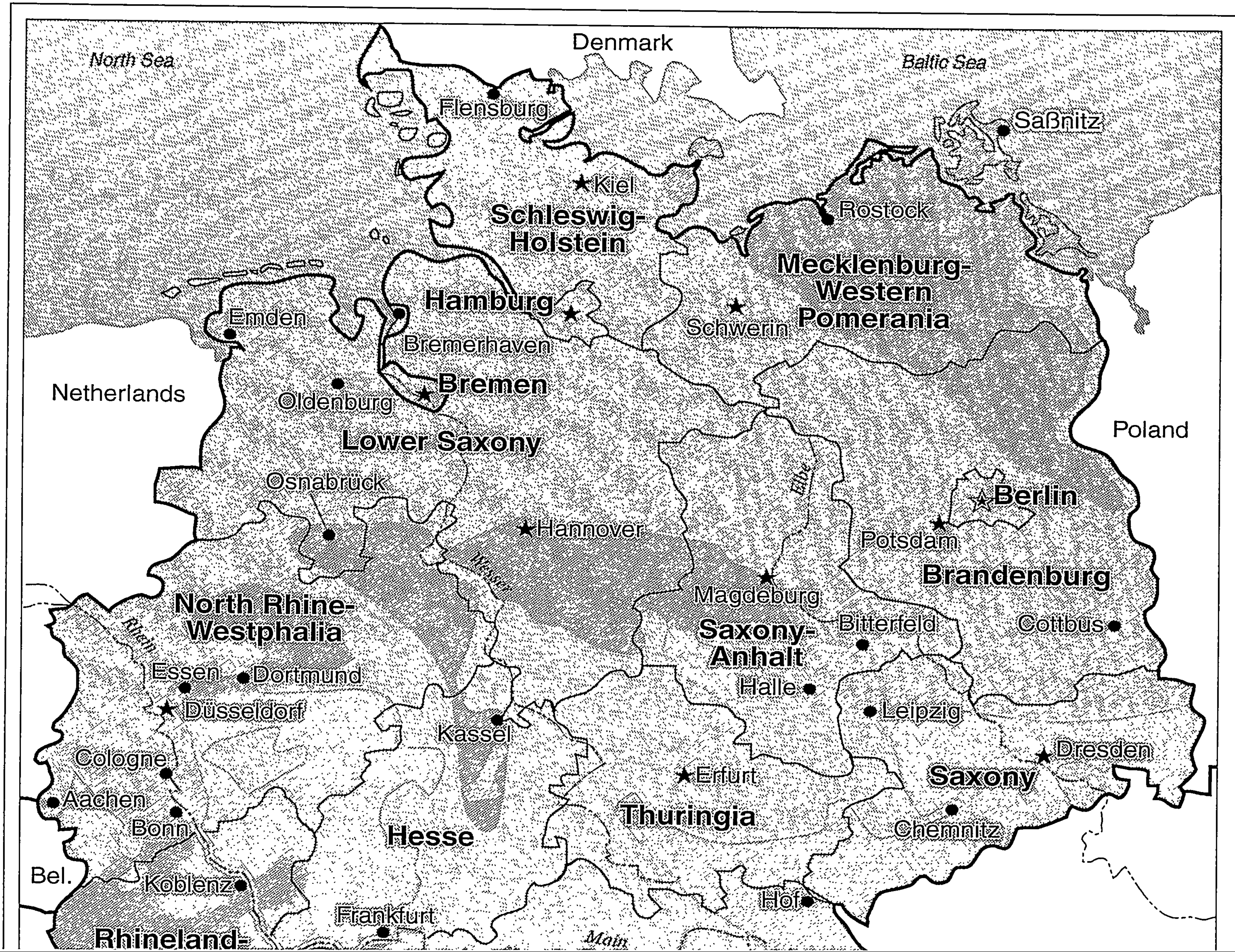
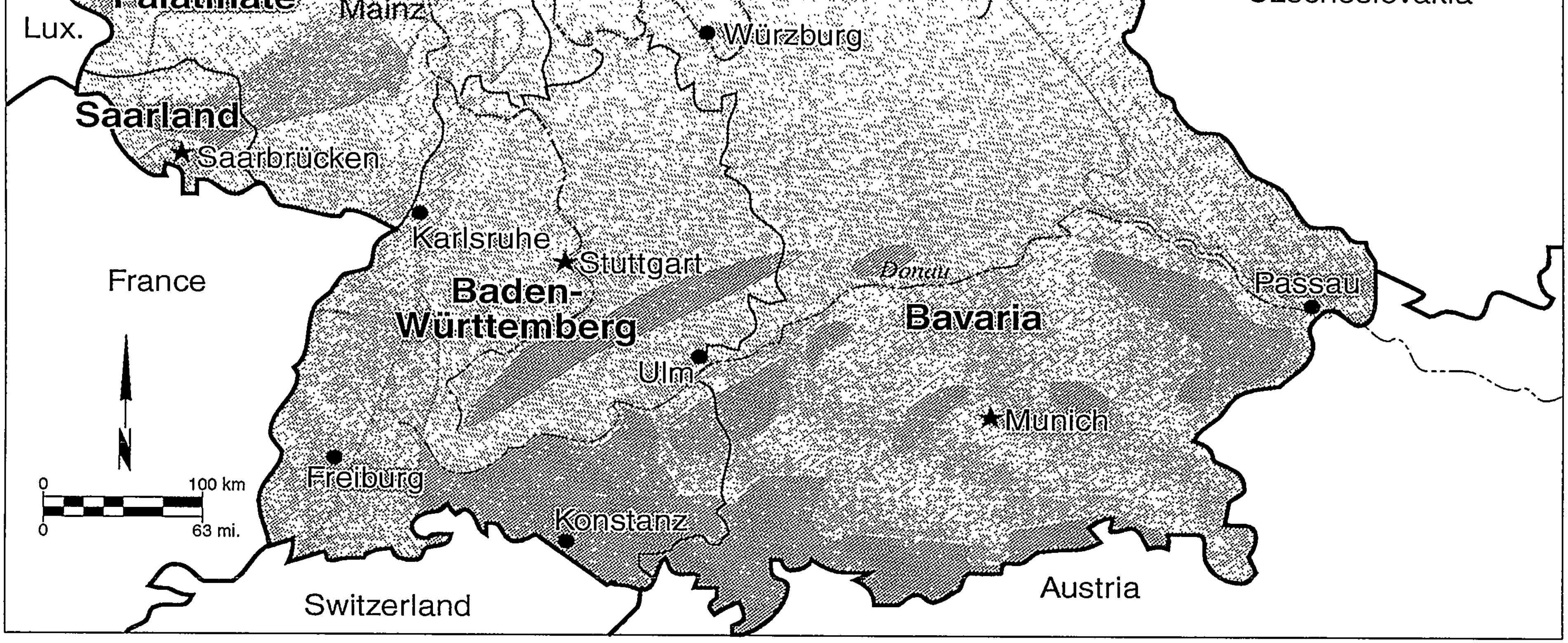


North Sea
Denmark
Baltic Sea
Flensburg
Saßnitz
Kiel
Schleswig-Holstein
Rostock
Mecklenburg-Western Pomerania
Emden
Hamburg
Schwerin
Bremerhaven
Bremen
Netherlands
Oldenburg
Lower Saxony
Poland
Osnabrück
Elbe
Berlin
Hannover
Potsdam
Weser
Magdeburg
Brandenburg
North Rhine-Westphalia
Rhein
Bitterfeld
Cottbus
Saxony-Anhalt
Essen
Dortmund
Halle
Düsseldorf
Leipzig
Kassel
Cologne
Dresden
Erfurt
Saxony
Aachen
Bonn
Hesse
Thuringia
Chemnitz
Bel.
Koblenz
Hof
Frankfurt
Rhineland-
Main



LEGEND

- ● Major City
- ★ State Capital
- National Capital
- Sea
- River

Porous, generally unconsolidated rocks. Moderately to highly productive aquifers. Glacial, glaciofluvial, and fluvial deposits of clay, silt, sand, and gravel.

Moderately-to highly-permeable rocks in fractured or karstified rocks, including chalk, limestone, dolomite, sandstone, and basalt. Aquifers are local to extensive and moderately to highly productive.

Low permeability rocks producing groundwater only in localized areas. Generally consists of moraine deposits and claystones in the north; slates, quartzites and claystone in the west; and moraine and Molasse deposits in the south.

Very limited groundwater resources. Very low permeability rocks including clays, claystones, slates, tuffs, intrusive igneous rocks, and low-to high-grade metamorphic rocks.

Source: (Bundesaustalt für Geowissenshaften und Rohstoffe und Unesco, 1977

FIGURE **2-7**
GENERALIZED HYDROGEOLOGIC MAP OF GERMANY
DOE/ITEP/WA

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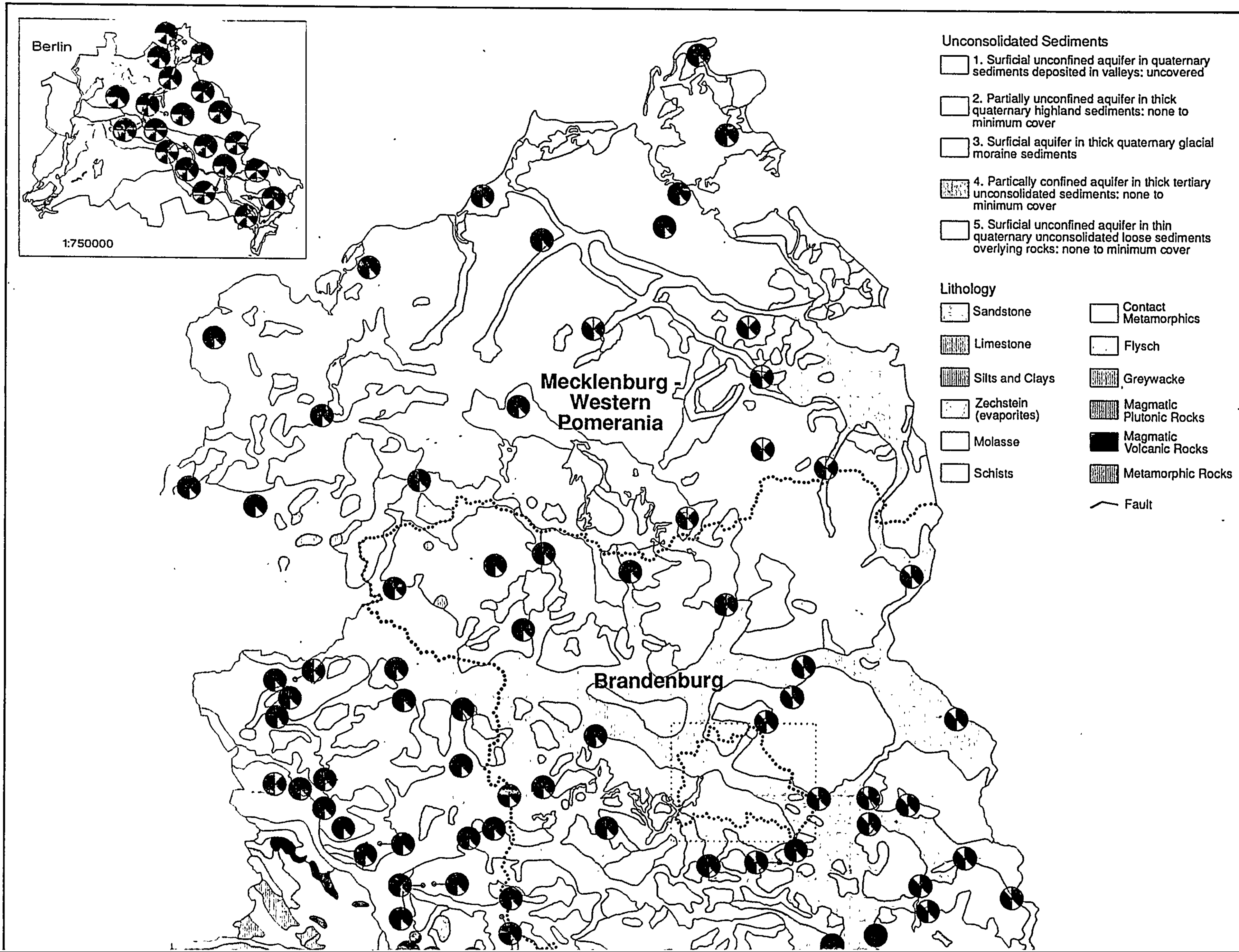
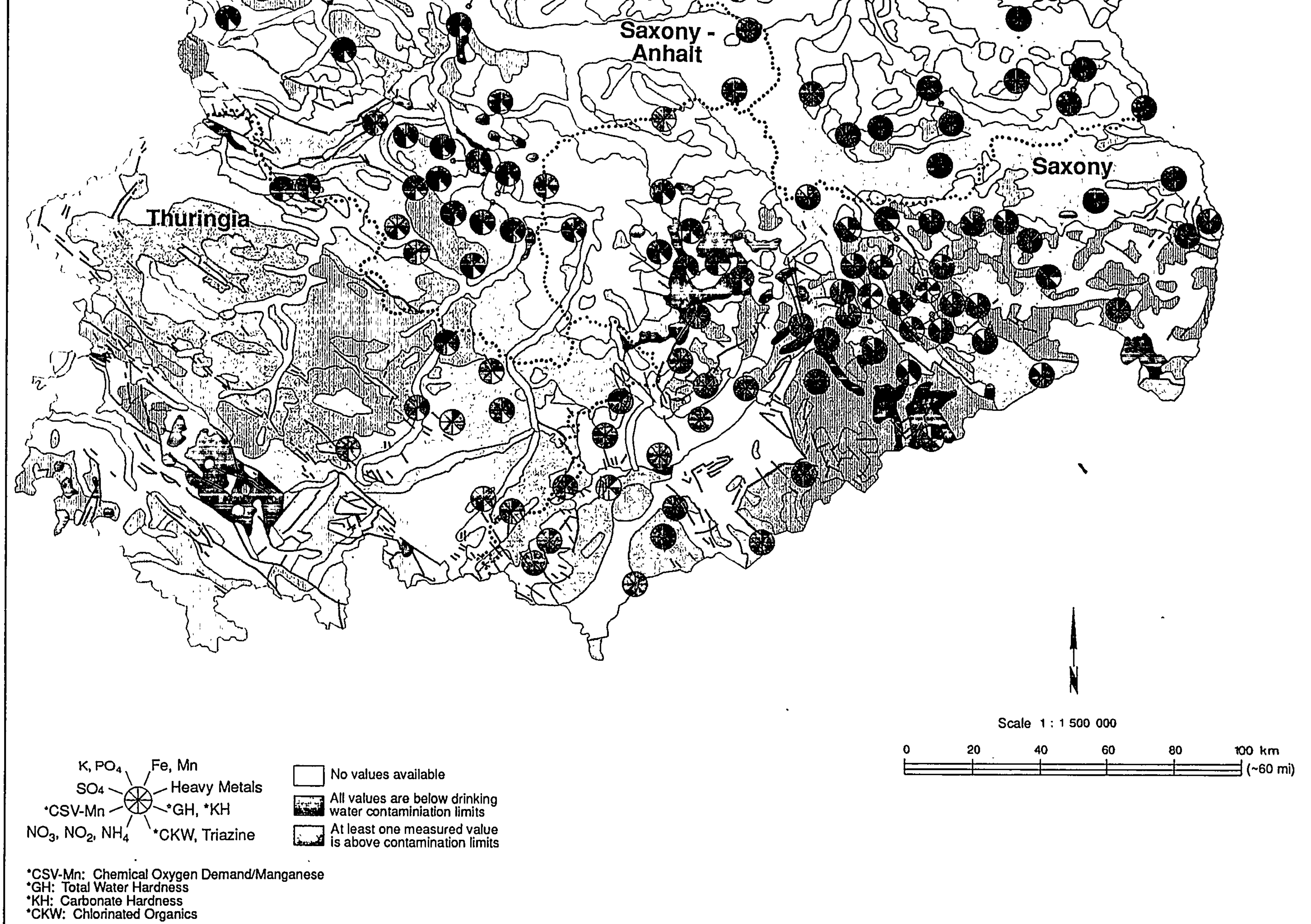

Berlin
1:750000
Mecklenburg - Western Pomerania
Brandenburg
Unconsolidated Sediments
1. Surficial unconfined aquifer in quaternary sediments deposited in valleys: uncovered
2. Partially unconfined aquifer in thick quaternary highland sediments: none to minimum cover
3. Surficial aquifer in thick quaternary glacial moraine sediments
4. Partically confined aquifer in thick tertiary unconsolidated sediments: none to minimum cover
5. Surficial unconfined aquifer in thin quaternary unconsolidated loose sediments overlying rocks: none to minimum cover
Lithology
Sandstone
Limestone
Silts and Clays
Zechstein (evaporites)
Molasse
Schists
Contact Metamorphics
Flysch
Greywacke
Magmatic Plutonic Rocks
Magmatic Volcanic Rocks
Metamorphic Rocks
Fault



Source: (Umweltbundesamt, 1992)

FIGURE **2-8**

GROUNDWATER CONTAMINATION IN EASTERN GERMANY(SPRING, 1990)

DOE/ITEP/WA

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deteriorated in many areas in recent decades because of industrialization and intensive agricultural production. Comprehensive surveys of the extent of groundwater contamination have not been performed in Germany, but implementation of systems for groundwater sampling is in progress (Federal Ministry for the Environment, 1992).

According to one source, fewer than half the people in eastern Germany have access to drinking water that meets European Community (EC) standards (US Dept. of Commerce, 1992). A 1990 sampling program indicated that approximately 5% of wells had an excessive content of volatile chlorinated organics (Federal Ministry for the Environment, 1992).

Further information on groundwater contamination in eastern Germany is presented in Figure 2-8. Chemical data are provided for approximately 200 groundwater sampling points, although not all chemical groups have been reported at each point. The chemical groups are reviewed below, with results based only on points with reported data.

- Iron and manganese concentration limits were exceeded in approximately 80% of samples reported, with high values detected in many areas of eastern Germany.
- Heavy metals concentration limits were exceeded in approximately 40% of the samples, including high values detected in the Halle and Lusatian regions.
- Total water hardness or carbonate hardness was exceeded in approximately 10% of samples reported, with high values commonly detected in the Halle area.
- Chlorinated organic concentrations were exceeded in approximately 15% of samples reported, particularly in the Dresden area.
- Nitrate, nitrite, and ammonium concentration limits were exceeded in approximately 40% of samples reported, with high values distributed across eastern Germany.
- Chemical oxygen demand limits were exceeded in approximately 25% of samples reported, with numerous high values detected in the Halle and Lusatian regions.
- Sulfate concentration limits were exceeded in approximately 20% of samples reported, particularly in potash mining areas.
- Potassium and phosphate concentration limits were exceeded in approximately 5% of samples reported, with high values noted at Halle and Magdeburg.

Comparable information for western Germany was not obtained.

2-2-5 Surface Water Contamination

Germany has relatively few lakes, with most located in the eastern and alpine regions. Germany is drained by four principal river systems: the Elbe, the Weser, the Rhine, and the Danube. Figure 2-9 presents estimates of water quality in major rivers within western Germany for 1990. In some areas of western Germany, rivers have been significantly impacted by point and non-point discharges of contaminants. Similar graphical information has not been obtained for eastern Germany. However, the following discussions describe river impacts in both eastern and western Germany.

The Elbe River basin includes approximately 75% of the land area of eastern Germany (referred to as the middle basin), and a relatively small portion of western Germany, including the Hamburg

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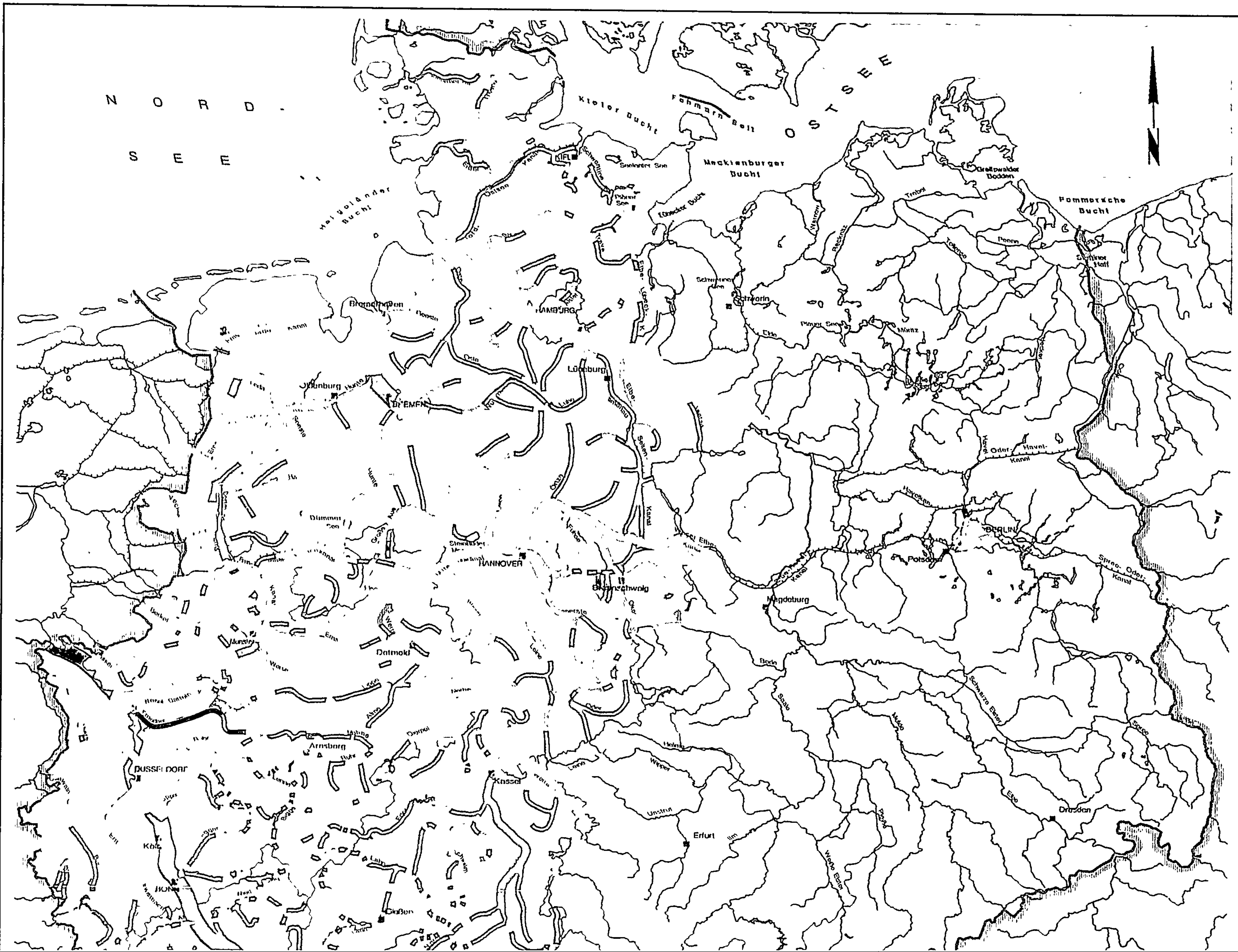
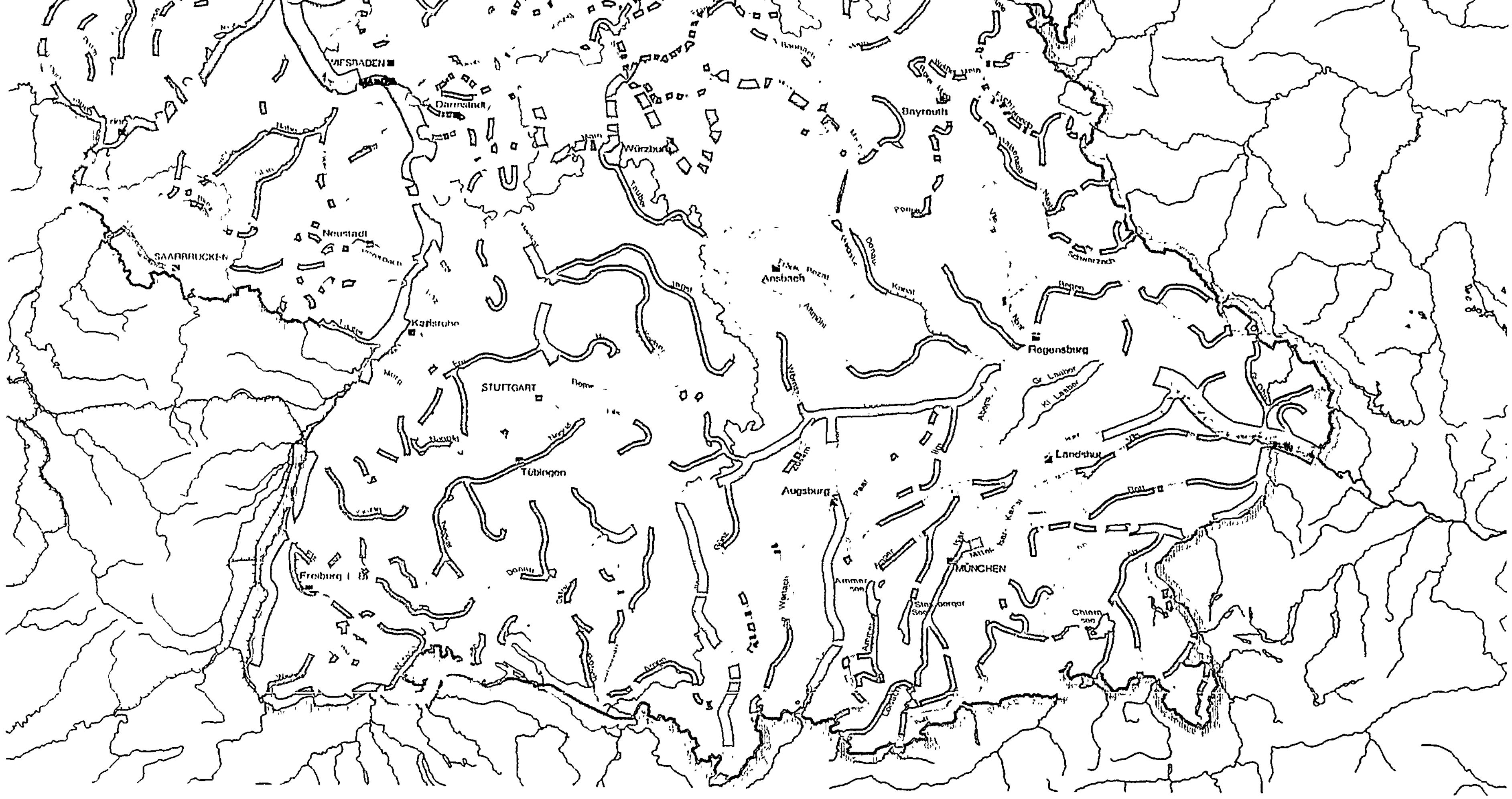

NORD-
SEE
OSTSEE
Kieler Bucht
Fehmarn Belt
Mecklenburger Bucht
Pommersche Bucht
Greifswalder Bodden
Helgoländer Bucht
Lübecker Bucht
KIEL
HAMBURG
Lüneburg
Schwerin
BREMEN
Oldenburg
HANNOVER
Braunschweig
Magdeburg
Potsdam
BERLIN
Dresden
Erfurt
Kassel
Dortmund
DÜSSELDORF
Arnsberg
Detmold
Gießen
BONN
Köln
Elbe
Elbe-Seiten-Kanal
Elbe-Lübeck-K.
Havel
Oder-Havel-Kanal
Spree-Oder-Kanal
Havelkanal
Schwarze Elster
Weiße Elster
Saale
Mulde
Unstrut
Wipper
Bode
Leine
Aller
Weser
Hunte
Ems
Lippe
Ruhr
Lahn
Dümmer See
Peene
Tollense
Recknitz
Warnow
Trave
Eider
Ilm
Plauer See
Müritz
Schweriner See
Plöner See
Spree
Oste
Stettiner Haff



Scale: Maßstab 1:2,500,000
0 50 100 km
0 63 mi

EXPLANATION:
Degrees of Water Quality

I	Uncontaminated
I - II	Low Contamination
II	Medium Contamination
II - III	Critical Contamination
III	Strong Contamination
III - IV	Very Strong Contamination
IV	Unusually Strong Contamination

Source: (Umweltbundesamt, 1992)

FIGURE **2-9**
WATER QUALITY OF RIVERS IN WESTERN GERMANY, 1990
DOE/ITEP/WA

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area (referred to as the lower basin). The headwaters of the Elbe River are in former Czechoslovakia. The upper Elbe basin includes most of former western Czechoslovakia (Bohemia), where the river is called the Labe. Several major industrial areas, including the Prague metropolitan region, discharge into the basin so that river water is already highly contaminated at the point where it crosses the German border.

The middle reach of the Elbe River is highly contaminated with oxygen-depleting substances, including pesticides and fertilizers. The oxygen level is unstable and can be acutely low, especially between Dresden (Saxony) and Magdeburg (Saxony-Anhalt). The middle and lower reaches of the Elbe River are highly contaminated with heavy metals, particularly mercury between Dessau and Magdeburg. The mercury concentration found in fish from the Elbe exceeds 5 mg/kg in many areas of the river (Umweltbundesamt, 1992). According to Frankfurter Allgemeine Zeitung, silt in the Elbe river is contaminated annually with 124 metric tonnes of lead, 22.5 metric tonnes of mercury, and 12.7 metric tonnes of cadmium (Haznews, 1991f).

Measurements at Schnackenburg (Lower Saxony) indicate the Elbe is highly contaminated with oxygen-depleting substances by the time it reaches this location. Very high concentrations of dissolved organic compounds, ammonium, chromium and cadmium, chloride, orthophosphates, total phosphorus, nitrate, lead, and nickel are also present. In the Elbe Estuary downstream of Hamburg, the oxygen concentration is extremely low during the summer months, and periodically has been measured at 0-mg/l (Umweltbundesamt, 1992).

Increased contamination of the Elbe River has been reported recently, including elevated levels of mercury, lead, copper, and chromium, because of the cleanup of industrial sites in eastern Germany. The environmental minister for Lower Saxony, Monika Griefahn, reported that while levels of toxic chemicals decreased from 1987-1990 due to closing of production facilities along the Elbe, levels of contaminants have increased significantly since 1990 due to contaminated site remedial activities near the river (Haznews, 1991f). Fifty-eight treatment facilities are being built to deal with pollution of the Elbe (European Chemical News, 1991).

The Weser River begins at the confluence of the Fulda and the Werra Rivers in central Germany near Kassel (Hesse). The Weser flows northwards in Lower Saxony through Bremen and meets the North Sea at Bremerhaven. The Weser is highly contaminated at its origin because of poor water quality in the Fulda and the Werra. Sampling of the Fulda River has indicated periodically high concentrations of chromium and cadmium, and elevated concentrations of orthophosphate and total phosphorus, nitrate, lead, and nickel (Umweltbundesamt, 1992). In the Werra, high concentrations of oxygen-depleting compounds and chloride, nitrate, total phosphorus, and heavy metals have also been measured. The oxygen concentrations of the Weser are generally unstable, and high pH values have also been measured. Pollution of the Werra is mainly a result of potash mining, located primarily in Thuringia (Umweltbundesamt, 1992).

The Rhine drainage basin encompasses more than a quarter of Germany's land area and several large metropolitan areas, including the Rhine-Ruhr area (Essen, Dortmund, Düsseldorf), the Rhine-Main area (Frankfurt and Mainz), the Rhine-Neckar area (Mannheim), Köln, and Stuttgart. The headwaters of the Rhine are in the Swiss Alps. The German portion of the river basin begins at Lake Constance (Bodensee) along the southwest border of Germany in Baden-Württemberg. The Rhine flows from the west end of Lake Constance generally along the Swiss border, then at Basel, Switzerland turns north forming the French/German border until approximately Karlsruhe. The Rhine flows entirely within Germany until the lower Rhine crosses into the Netherlands downstream of Düsseldorf (North Rhine-Westfalia).

Pollution in the Rhine includes elevated chloride, nitrate, lead, chromium, and nickel concentrations, and periodic low oxygen concentrations. The German association of water plants, Arbeitsgemeinschaft Rhein-Wasserwerke, reports that nitrate pollution in the Rhine River has continued to increase while pesticide pollution has decreased to the point that only four of forty pesticides are above the limit of 0.1 µg/l (Handelsblatt, 1989).

Several tributaries to the Rhine contain significant amounts of contamination. The Neckar River is highly contaminated with fertilizers and pesticides, such as ammonium nitrate and orthophosphates, and has low oxygen concentrations. The Main River also has high concentrations of fertilizers and pesticides. In 1982, a record low oxygen concentration of 0.2 mg/l was measured in the Main. Since that time, the oxygen levels have increased because of improved water treatment facilities. Other rivers include the Mosel, Seig, Erft, Ruhr, and Lippe, which generally contain significant amounts of lead, chromium, cadmium, and other heavy metals, and elevated chloride levels (Umweltbundesamt, 1992).

The Danube (Donau) River begins in the southwest of Baden-Württemberg and runs eastward through Bavaria, crossing into Austria at Passau. The Danube eventually drains into the Black Sea in eastern Europe. The Danube is relatively clean. Impacts are generally from agricultural runoff and include elevated orthophosphate and nitrates. In Dillingham (Bavaria), heavy metal concentrations are slightly higher than elsewhere in the Danube and may be due to tributaries such as the Inn and Salzach Rivers flowing from Austria (Umweltbundesamt, 1992).

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3 ENVIRONMENTAL REGULATIONS IN GERMANY

The environmental regulations in Germany are considerably different from other European countries. Germany has the strictest environmental laws in Europe and its industry has become a leader in the fields of waste minimization and environmental safety. It is uncertain what effect the European Community will have on these regulations; German industry would have a considerable advantage over competitors in benefitting from any increase in environmental regulations throughout Europe.

The implementation of environmental regulations in Germany is somewhat unique and certainly in contrast to the way similar laws are administered and enforced in the US. These differences can be attributed largely to the distribution of legislative and administrative responsibilities in Germany as defined by their constitution. This section provides an overview of the governmental system in Germany and reviews the process for legislating and administering environmental laws and regulations. Legislation pertaining to waste disposal, water quality, radioactive waste, contaminated sites, environmental restoration, and public disclosure is discussed.

3-1 Federal and State Responsibilities

To understand German environmental laws and their administration, it is important to understand their system of government. The following summary provides an introduction to the structure of the federal and state governments in Germany and the division of power within them. Much of the information is an abstract from "The Europa Year Book" (Europa Publication Ltd., 1990).

The Federal Republic of Germany is made up of 16 constituent states (Länder). The Federation operates according to the articles contained in the Basic Law (Grundgesetz), which was imposed on the British, French, and US zones of occupation in Germany in 1949. It was intended as a provisional Constitution to serve until a permanent one could be drawn up but it has endured with little change. The Basic Law recognizes two categories of federal legislation: those matters that require national laws in the interest of the entire community (e.g., foreign affairs, defense, currency, etc.) and those that involve cultural and communal affairs (e.g., schools, the media, regional planning, conservation, etc.). In the latter case, the Federation may establish the framework or general rules, but it is up to the state to implement the laws in such a way that is consistent with its economic, social, and cultural circumstances. The Basic Law established a system where the Länder, while subject to the authority of the Federation, are also involved in the formation of public policy. Neither the Federation nor the Länder can act of their own accord.

The legislative branch of the federal government consists of a Lower and Upper House. The legislative organ of the Federation is the Federal Assembly (Bundestag), the Lower House of Parliament. Members to the Bundestag are chosen in a general election that combines constituency and proportional representation. Each voter has two votes: one for a named candidate and one for a party. Votes cast for candidates elect the constituency representatives, whereon votes for a party entitle that party seats in parliament according to the proportion of the votes they receive. A party must receive at least 5% of the total to be represented. Bills from the government are introduced through the Bundestag, which has primary responsibility for passing laws, particularly those laws that do not directly influence the interests of the Länder. After adoption, the bills must be submitted to the Federal Assembly (Bundesrat) for consideration.

The Länder retain a strong influence over legislation through the Bundesrat, the Upper House of Parliament. The members of the Bundesrat are appointed by the Land (State) governments. Each Land has at least three votes; those with more than two million inhabitants have four, and those with more than six million inhabitants have five. The votes of each Land in the Bundesrat may only be given as a block vote reflecting the interests of the Land and not the individual members.

The right of legislation lies within the Länder insofar as the Basic Law does not specifically accord legislative powers to the Federation. Distinction is made between fields of exclusive legislation of the Federation and fields of "concurrent" legislation of the Federation and the Länder. For concurrent legislation, the Länder may legislate so long and so far as the Federation makes no use of its legislative right. The Federation has this right only insofar as a matter cannot be effectively legislated by state regulation, or the regulation by Land law would prejudice other Länder, or if the preservation of legal or economic unity demands regulation by federal law. Exclusive legislation of the Federation is strictly limited to such matters as foreign affairs, citizenship, currency, customs, etc. Approximately half of all federal laws require the consent of the Bundesrat who have absolute veto over measures that would seriously affect the financial or administrative interests of the Länder (such as tax laws).

Compared with heavily centralized countries like Britain, the Federal Republic of Germany gives regional politicians a great deal of scope. The Länder execute the federal laws as their own concern insofar as the Basic Law does not otherwise determine. In doing so, they regulate the establishment of the authorities and the administrative procedures. The federal government exercises supervision to ensure that the Länder execute the federal law in an appropriate manner. The Länder can also legislate where the Federation has no constitutional authority to do so; however, the Federation has assigned itself responsibility for nearly all of the important areas of legislation.

The federal government (Bundesregierung) consists of the federal Chancellor and the federal ministers. The Chancellor is elected by an absolute majority of the Bundestag on the proposal of the federal President. Ministers are appointed and dismissed by the President upon the proposal of the Chancellor. The Chancellor determines general policy and assumes responsibility for it, but within these limits each minister directs his/her department on his/her own responsibility. The federal President is elected by the Federal Convention consisting of the members of the Bundestag and an equal number of members elected by the Länd governments. The President represents the federation in international law.

In general, the debate about the proper balance between prosperity and pollution is more fervent in Germany than elsewhere in Europe. The combination of wealth, high population density, and intensive industrialization makes the Germans both infatuated with a high standard of living and fearful of the consequences. As a result, the environment (Umwelt) has become a major political and industrial force. The Green Party, born out of the peace movement at the end of the 1970s, won representation in the Bundestag in 1983 and appears to be an established part of German politics. They have been a catalyst for bringing environmentalism to the forefront of politics and recognized early on the shift in western Germany's economy from the traditional areas of heavy industry to the more technology-based, less energy intensive manufacturing. The popularity of environmentalism with the public has resulted in substantial parts of the Green's basic ecology policies being incorporated into the mainstream parties (Christian Democratic Union and the Social Democratic Party).

Environmentalism is developing into a major economic growth area in Germany. Approximately 440,000 jobs (2% of western Germany's work force) are associated with protecting the environment (Federal Ministry for the Environment, 1992), although they do not completely compensate for the jobs lost through environmental policies. Environmental consciousness has generally benefited the chemical industry, for example, forcing it to abandon the production of polluting bulk chemicals into more profitable higher-value activities.

The Unification Treaty between the Federal Republic of Germany (West Germany) and the German Democratic Republic, (East Germany) places particular emphasis on the significance of protecting the environment. Under the treaty, the federal and state legislators are required to promote uniformity in ecological living conditions, i.e., at a minimum, the environmental conditions in eastern Germany should be brought up to the level in western Germany. The unification of Germany and the subsequent collapse of the economy in eastern Germany have resulted in a large number of unemployed workers. The opening of the eastern German economy to the standards of the market economy made it clear that many environmentally disastrous and outdated production processes were not competitive. The previously lax environmental laws and regulations resulted in devastating pollution in many of the industrial areas and discernible health effects. The discontinuation of these industries had an immediate improvement on environmental conditions in the region, such as air quality, but also involved the loss of jobs.

The Environment Ministry was established in 1986 by Chancellor Kohl. The ministry has been very active in trying to push through stricter controls at the federal level. However, it has limited influence over the implementation of environmental regulations in the Länder where there is a great deal of variability in how the regulations are carried out and administered. The Ministry of Environment recently published a memorandum on environmental cleanup and development in the new Länder. The main goals are to:

- achieve high environmental standards in the entire Federal Republic by the year 2000;

- continue environmental policy making; and

- continue assuming responsibility for the environment in the European and global context.

The supply side of the market is prepared to step in with scientific expertise, technology, and environmental management. There are over 4,000 "environmental" firms in Germany. However, one of the objectives of the federal government is to create jobs to replace those lost due to environmental standards that came with unification. The Federal Institute for Employment is providing resources to utilize the work forces of companies that were closed for the rehabilitation of the environment in the new Länder. In addition to these direct assistance measures, other federal programs are being used to develop an environmental infrastructure at the local levels. A total of DM 1,700-million was allocated in 1991 for assistance measures and loans (Federal Ministry for the Environment, 1992). For example, DM 225 million was allocated to Saxony-Anhalt to begin cleaning up the environment in the Bitterfeld region, one of the most polluted regions in eastern Germany. An additional DM 300-million is being used to establish companies to perform the cleanup activities for contaminated sites in the state. These firms are expected to employ around 20,000 workers by 1994. The environmental foundation of the chemical, paper, and ceramics trade union in the area has set up an environmental advisory bureau in Bitterfeld to assist companies and organizations carry out environmental projects using local unemployed workers (Haznews, 1991d).

For waste- and contamination-related issues, there is a mixture of federal and state responsibilities. The basic law on waste, normally referred to as the Abfallgesetz (AbfG), is a federal law. As the Länder are responsible for implementing the objectives of the federal law, they have their own complementary waste laws. Nevertheless, in the case of special waste (Sonderabfall), a set of detailed regulations (TA Abfall) has been published at the federal level. Similarly, disposal of radioactive materials is clearly defined as a federal responsibility, although the relevant law (the Atomgesetz), is being amended to transfer this responsibility to the waste producers.

For contamination, the position is less clear because, as will be seen in Section 3-5, there is no specific federal legislation or regulation directly related to contaminated sites.

3-2 Waste Disposal Laws and Regulations

3-2-1 Federal

In 1986 the law on the avoidance and disposal of waste (Gesetz über die Vermeidung und Entsorgung von Abfällen) replaced the 1972 federal waste law. The current law, that is known as the Abfallgesetz (AbfG), has the objective of ensuring that unavoidable waste is used or disposed of in ways that do not cause any environmental impairment. The law can be applied to facilities which existed prior to 1972 in cases concerning the welfare of the public (Wohls der Allgemeinheit).

The law and the related regulations, such as the waste definition ordinance (Verordnung zur Bestimmung von Abfällen), are applied through measures directed particularly at the possessors of waste and at the owners of disposal facilities. There is a general obligation to dispose of waste only in permitted facilities. In the case of especially hazardous waste (besonders überwachungsbedürftigen Abfällen or Sonderabfall), this is strengthened by the requirement to obtain a certificate of acceptance from the disposal facility.

The law requires that disposal facilities are subject to permitting processes, which will generally involve the participation of public bodies. In the case of special waste, federal regulations have been published covering many aspects of the design, construction, and operation of facilities for their disposal. These regulations are known as TA Abfall (Technische Anleitung zur Lagerung, chemisch/physikalischen, biologischen Behandlung, Verbrennung und Ablagerung von besonders überwachungsbedürftigen Abfällen). An equivalent federal set of regulations for municipal waste, known as TA Siedlungsabfall, is in draft form. Under the federal law, an owner of a waste disposal facility has to advise the responsible authorities when it is taken out of use and is then responsible for taking precautions to prevent impairment of the environment.

The federal law envisages that implementation of waste disposal will be based on obligatory Land-level plans and that Land laws will define, for example, the responsible authorities for permitting and for supervision of disposal facilities. Responsible public bodies, as defined under Land laws, have the duty of making arrangements to guarantee the disposal of wastes arising in their areas. Possessors of waste which is not suitable for disposal with domestic waste (Hausmüll) must provide information on their waste at the request of the responsible authority. Similar requirements apply to owners of disposal facilities and to current and previous owners of plots of land where wastes were generated, handled, or stored before the federal law came into force. In spite of these regulations and the public attention given to environmental concerns, companies that violate environmental regulations often face only modest penalties.

It is a requirement of the federal law that a responsible person (Betriebsbeauftragte) is appointed by each facility which generates hazardous waste and by each facility involved in waste handling or disposal. This person's role is to supervise the compliance of the facility operation with the waste-related laws, regulations, and instructions of responsible authorities.

Draft proposals exist for a federal waste tax. As presently envisaged this would be applied both at the point of waste generation and at disposal in, for example, a landfill. The Federal Ministry for the Environment has drafted a proposed federal waste tax law that would raise DM 5,000-million per year in fees. The bill is not expected to be introduced before the end of 1992 and is unlikely to come into force until 1994.

3-2-2 State

Under the individual Länder (Bundesländer) waste laws, the normal arrangement is that the public bodies responsible for waste disposal are defined as the towns/cities (Städte) and the districts (Kreise). These bodies may set their own statutes to control the implementation of their obligations with respect to waste disposal.

Within each Länder, different arrangements are made for dealing with special waste. This frequently involves the use of defined disposal sites and organizations. The definition of special waste is waste that is dangerous because of its kind or amount and that presents a risk to health. The risk can result from the toxicity, flammability, or explosive nature of the substance. The special waste law, in effect since 1984, requires that a competent authority be notified when waste is produced. There is a subset of materials that has more strict regulations requiring monitoring from the time they are produced to disposal (referred to as "special-special waste").

3-3 Water Management Laws and Regulations

The basic federal law concerning water quality and its protection is the water management law (Gesetz zur Ordnung des Wasserhaushalts). This is generally referred to as the Wasserhaushaltsgesetz (WHG). The management of the water system is controlled through a combination of federal and state laws and regulations. Of particular concern is the public water supply, which always has precedence. There are several broad objectives, including the prevention of contamination or other impairment of water resources, minimization of water consumption, and disposal of waste water without impairing the welfare of the public. The laws concern surface, underground, and coastal waters. The measures are directed mainly at owners of water resources, owners and users of plots of land, and owners of facilities. A basic requirement of the law is that, where intended measures can have an adverse effect on water resources, the necessary care is to be taken to prevent these from occurring.

Another basic feature of the law is that use of water resources normally requires permission, and that in this context use includes disposal of waste water and other waste materials. Depending to some degree on the nature of the permit, later supplementary regulations may be applied, or the permit may even be withdrawn, if the observed effects are considered by the responsible authorities to be undesirable.

Regulations published under the law include minimum requirements for waste water discharges for specific types of operations. The basic objective is to keep the discharged amounts of defined contaminants as low as possible, considering current technology. An example of such a regulation would be that applying to discharges from mineral ore processing facilities (Allgemeine Verwaltungsvorschrift über Mindestanforderungen an das Einleiten von Abwasser in Gewässer —Erzaufbereitung). This is generally referred to as the 27. AbwasserVwV. Implementation of the water management laws and regulations is mainly carried out by state authorities.

3-4 Laws on Radioactive Materials

Two federal laws concern the control of the environmental effects of radioactive materials. The first of these, the nuclear power law (Gesetz über die friedliche Verwendung der Kernenergie und den Schutz gegen ihre Gefahren), is normally referred to as the Atomgesetz (AtG). This law has two principal objectives: (1) the development of nuclear energy to supply electrical power; and (2) ensuring protection from the hazards associated with its use. The second law protects the population from exposure to radiation (Gesetz zum vorsorgenden Schutz der Bevölkerung gegen Strahlenbelastung). This is normally referred to as the Strahlenschutzvorsorgesetz (StrVG). The objectives of this law are to protect the population by observing radioactivity in the environment and taking appropriate measures when events are detected which could have significant radiological effects.

Implementation of the Atomgesetz is a federal responsibility, except as far as the permitting of nuclear installations is concerned. This process also involves the Länder concerned. Federal bodies have been established to advise on matters of radiation protection (Strahlungschutzkommission) and nuclear reactor safety (Reaktorsicherheitskommission), and these bodies work closely with the relevant international organizations.

In the current version of the Atomgesetz it is clear that provision of a repository (Endlager) for nuclear waste is a federal responsibility, although the Länder must provide facilities for its temporary storage (Zwischenlager). The responsibility for the final repository is the subject of discussion, and it is expected that this will be changed in some way. Some waste from nuclear power operations has been placed in repositories in Germany, and permission has recently been given for this to be continued.

3-5 Contaminated Site Law

3-5-1 Federal

In general terms, the law on environmental liability requires that the originator of environmental damage be held responsible. However, it has been recognized for some years that the available federal laws are insufficient as far as the remediation of contaminated sites (Altlasten, former waste disposal sites; Altstandorte, former industrial sites; Altanlagen, former facilities) is concerned. There is no specific law which clearly defines the various responsibilities and requirements with respect to remediation. In these situations, appeals are often made to other environmental laws and regulations, such as the laws on waste, emissions, and water management (Abfallgesetz, Immissionsschutzgesetz, and Wasserhaushaltsgesetz), and also to more general legislation relating to the maintenance of public order, such as the Polizei und Ordnungsrechts.

There are a number of serious deficiencies with the application of these laws and regulations as far as remediation is concerned. Principal among these are:

- The measures that may be ordered to protect public health often do not extend to the remediation of contaminated sites.

- It is very difficult to ensure that remediation measures are financed by the responsible party and out of public funds, even when the probable cause of the contamination is established.

A dramatic example of the second point is a contaminated site in the town of Marktredwitz located in Bavaria. The town is the location of the Chemische Fabrik Marktredwitz, a 200-year-old chemical works in the center of town. In the 1980s, investigators discovered high concentrations of mercury in a nearby stream. Upon further investigation, the factory site was found to be contaminated with massive amounts of arsenic, antimony, cadmium, cyanide, phenol, and mercury. The substances were allowed to build up in vessels over several decades, and large amounts of the materials found their way into the underlying soil and groundwater. After a three-month trial, the two managers of the factory were fined a total of DM 190,000. Cleanup costs are estimated at over DM 50-million. Because the company has declared bankruptcy, the Länder is responsible for paying for remediation.

Because of the inadequacy of the existing law, a draft federal ground protection bill (Bodenschutzgesetz) has been submitted to Bundestag for discussion. Due to the contentious nature of the proposed law, it is unlikely that it will be passed in the near future.

3-5-2 State

In the absence of suitable specific federal legislation, dealing with contaminated sites is a Länder matter under the terms of the constitution (Grundgesetz). Many of the Länder have amended their waste law (Landesabfallgesetz) to include some guidance on the procedures to be followed with respect to contaminated sites. In general, the following steps are followed:

1. Known and suspected contaminated sites are identified and located, followed by a preliminary assessment of the potential risks involved.

2. Detailed site investigations are performed to determine the extent of the contamination and whether suspected sites represent actual risks. The sites are then ranked according to a set of criteria to set priorities.

3. Remediation activities are carried out on the sites posing the greatest threat to health and safety while the conditions at less contaminated sites are monitored until the contamination problems can be addressed.

The large number of known and suspected contaminated sites in Germany and the high cost associated with cleaning them up means that only a small percentage of the sites will be remediated in the near future. A special problem is that of financing. The normal principle in environmental matters in Germany, i.e., those causing the contamination should pay for remediation (Verursacherprinzip), cannot always be applied. It is often impossible to identify the responsible parties for older sites, or the company involved may no longer be operating. In eastern Germany, industry was federally owned and operated. In such cases the next step is often an attempt to make the landowner pay (buyers of eastern German properties after unification are exempt for any damage caused prior to July 1, 1990). If this fails, the Länder and community become liable for the costs although many will rely on federal sources because the Länder and community are already heavily indebted. Recently, several different approaches have been developed for distributing the costs between the Länder and federal governments and private industry. Section 3.7 discusses several Länder tax laws for covering some of these costs.

3-6 Contaminated Site Cleanup Criteria

There are no standard federal criteria (Grenzwerte) for use either in evaluating contamination at a site or in designing a remediation program. The basis of much of the legislation and regulation used in connection with contaminated sites is that of preventing danger to the public, and this very often means a health risk. This implies that part of a site evaluation or of design of a remediation program must be a risk assessment procedure.

Practically, it is found to be useful to be able to compare measured values with published values, at least for preliminary purposes. Several sources are in general use as references. These include the so-called Dutch list, which was developed by the environmental authorities in the Netherlands. This gives three concentration levels for a large number of potential contaminants in soil and in groundwater. The three levels (A, B, and C) were intended to represent, respectively, a background or reference level, a level requiring further investigation, and a level requiring remediation. Although the list has found wide application outside the Netherlands, the Dutch themselves are understood to be preparing to change some values. For contaminant concentrations in drinking water, reference is made to the World Health Organization and European Economic Community guidelines (Richtwerte) and to the federal regulation (Verordnung über Trinkwasser und über Wasser für Lebensmittel betriebe). This is generally known as the Trinkwasserverordnung (TrinkwV). Several lists are also produced by individual Länder, and some of these have found wider application. For soil to be used for cultivation, for example, the so-called Klocke list was produced in Baden-Württemberg. Hamburg and Berlin have also published their own lists.

3-7 Liability for Environmental Damage

Implementing the principle that those causing damages should pay for it (Verursacherprinzip) is a recent federal law. This environmental liability law (Gesetz über die Umwelthaftung) came into force at the beginning of 1991. It is known as the Umwelthaftungsgesetz (UmweltHG).

The basic objective of this law is to make the owners of defined types of facilities pay compensation for personal or material damage resulting from any environmental effects of their facility. Environmental effects are defined as those in which significant contamination is spread through the ground, water, or air. However, the law does not apply if a facility was operated in accordance with the relevant environmental protection regulations and permits or if there has not been an operational defect or disturbance. For closed facilities, the owner at the time of closure is liable, but only for damage caused after the law came into effect.

Another exemption is given to companies or investors purchasing property in the Länder in eastern Germany. According to Section XII of the Unification Treaty, the exemption clause provided for in the Framework Environment Act (Umweltrahmengesetz) applies (Franzius and Stietzel, 1991). According to the act, the company or persons who own installations used for commercial purposes or within the framework of economic undertakings are not liable for any damage caused prior to July 1, 1990 as a result of the operation of the installation. Exemptions are determined after the interest of the purchaser, the general public and environmental protection have been weighed. Subsequent liability due to claims based on civil law remains unaffected. The purpose of the exemption is to prevent the abandoned sites from deterring potential investors.

Several Länder have introduced waste tax laws. For example, the State Waste Management and Contaminated Site Law was passed in April 1991 in Rhineland-Palatinate. Under the law, if a land owner has a questionable site and fails to take action, the supervisory authorities have the right to perform a risk assessment and charge the cost to the owner if the area in question is found to be contaminated. Baden-Württemberg recently passed a special waste tax law. Approximately DM 13-million was collected during the first year with the funds used for environmental protection activities. The administration in Hesse has introduced a similar waste tax law. A draft law to pay for the cleanup of contaminated abandoned munitions sites was proposed by Lower Saxony on behalf of all other German Länder. The law would require the federal government to fund the cleanup of the sites.

4 ENVIRONMENTAL RESTORATION TECHNOLOGIES IN GERMANY

Several technologies for waste management and environmental restoration have been and are being developed and applied to address the environmental needs in Germany. Some of these technologies may be more efficient, less expensive, more acceptable, and safer than those being considered by the DOE to meet their environmental cleanup needs. The identification and transfer of such technologies to appropriate waste management and environmental restoration programs in DOE are major objectives of ITEP.

To accomplish the objectives of ITEP, a survey of environmental problems and mature and developing environmental restoration technologies in Germany was performed. This section provides a compilation of German technologies of potential interest to the DOE. The information provided is limited to identifying technologies, i.e., no attempt was made to perform an evaluation of the attributes of a technology or to make a comparison with similar technologies in the US. The evaluation phase will require a more detailed investigation and is outside the scope of work for this project. References and a point of contact is provided for each technology to allow the reader to obtain additional information if desired. A second constraint was that the survey was limited to environmental restoration technologies. A significant portion of the environmental research and development funding in Germany and numerous fully developed technologies address waste management needs. Interested readers are directed to BMFT (1989, 1991a, and 1991b) for more information in this area.

4-1 Survey Approach

The information collected in the survey consists of the identification and brief description of either experimental or recently developed environmental restoration technologies in Germany. To make the process as relevant and complete as possible, the following approach was used:

1. Categories of generic environmental restoration activities were identified based on the needs of the DOE.

2. Colleagues from German environmental engineering firms identified standard practice technologies in each of the categories.

3. A literature review was performed to identify mature but non-standard as well as new technologies for environmental restoration.

4. Government ministries, national research establishments, universities, and industries were contacted to ascertain the types of new technologies being developed.

5. The technologies were categorized in terms of the generic environmental restoration activities and summary information was incorporated in a tabular format.

6. References and points-of-contact related to the technologies were compiled and tabulated to facilitate follow-on activities.

The primary categories of waste management and environmental restoration activities for the DOE complex are discussed in DuCharme et al., 1992. The categories consist of:

- waste generation/minimization;
- waste characterization;
- waste treatment;

- waste transportation/storage;
- site characterization;
- waste disposal;
- in situ treatment;
- in situ containment;
- waste removal; and
- site monitoring.

The relationship between the various categories of activities is shown in Figure 4-1. The categories form the basis for grouping the German environmental technologies, presented in Section 4-2. While the categories provide a useful format for grouping technologies, the applicability and effectiveness of a particular technology will obviously depend on the characteristics of the waste and site conditions present.

The set of "standard practice" technologies for each of the categories were developed and based primarily on discussions with environmental engineers at Golder Associates Umwelttechnik GmbH and Clausthaler Umwelt und Reservoir Engineering GmbH. Supplemental information was obtained by a literature review and conversations with staff at other governmental and research organizations.

The literature review included searches of sources in both the US and Germany. Several databases were accessed to search for information concerning environmental restoration technologies. These databases are summarized in Table 4-1. The information obtained was supplemented by several references that contain a compilation of restoration case histories of environmental technologies. The principal references include:

- descriptions of European case studies (EPA, 1992);

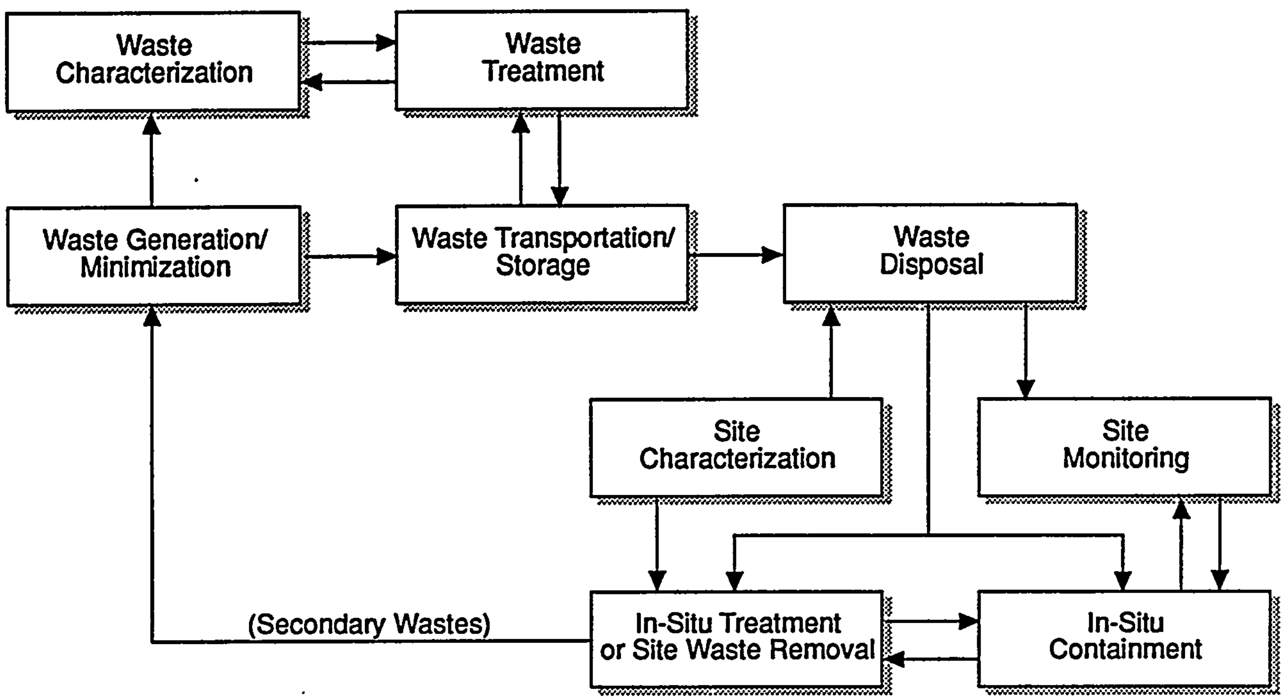
- a compendium of international environmental technologies (Nunno et al., 1990);

- the proceedings for a NATO/CCMS Conference on Demonstration of Remedial Action Technologies for Contaminated Ground and Groundwater (Wolf et al., 1988);

- an environmental research program report by the Ministry for Research and Development (BMFT, 1991b) and a compendium of their projects (BMFT, 1991a); and

- an ITEP report regarding the evaluation of specific foreign technologies (DuCharme et al., 1992).

The primary funding agencies, industries and universities involving environmental research and development in Germany were also contacted. In addition, market research performed by the US Department of Commerce in the area of environmental technology and pollution control in Germany was also reviewed for additional companies, facilities, and services.



NOTE: The applicability and effectiveness of various technologies to each of these activities will depend on the specific site and waste conditions involved (DuCharme et al, 1992)

FIGURE **4-1**
WM/ER ACTIVITIES
DOE/ITEP/WA

PROJECT NO. 913 1248.500 DRAWING NO. 23766 DATE 10/2/92 DRAWN BY TK

Golder Associates

TABLE 4-1. DATA BASES USED TO IDENTIFY ENVIRONMENTAL RESTORATION TECHNOLOGIES IN GERMANY

Database	Description	Contact
FTN	Reports on publicly funded research in science and technology in Germany (German and English).	Access data base through major public libraries in Germany
FBR	Literature on projects sponsored by the BMFT (German).	Access data base through major public libraries in Germany
UFOR	Summaries of current and completed environmental research and development projects in Germany, Austria, and Switzerland (German with English translations of title and abstract).	DATA-STAR D-S Marketing Inc. 485 Devon Park Dr. Wayne, PA 19087 (800) 221-7754
PTS Newsletter	Contains full text of articles from over 400 business and trade newsletters covering nearly 40 industries, subject areas, and ecopolitical regions.	DIALOG Information Services, Inc. 3460 Hillview Ave. Palo Alto, CA 94304 (800) 334-2564
NTIS	National Technical Information Service consists of government-sponsored research, development, and engineering, plus analyses prepared by federal agencies and their contractors. Includes reports from NASA, DDC, DOE, HUD, DOT, Department of Commerce, and 240 other agencies.	DIALOG Information Services, Inc. 3460 Hillview Ave. Palo Alto, CA 94304 (800) 334-2564
McGraw Hill Publications Online	Provides complete text for major McGraw-Hill publications, including: Business Week, Chemical Engineering, Biotechnology Newswatch, Green Markets, Industrial Energy Bulletin, Integrated Waste Management and many others.	DIALOG Information Services, Inc. 3460 Hillview Ave. Palo Alto, CA 94304 (800) 334-2564
INFOMAT	Provides English-language abstracts of business news articles appearing in more than ten languages from over 500 international business newspapers and journals.	DIALOG Information Services, Inc. 3460 Hillview Ave. Palo Alto, CA 94304 (800) 334-2564
ENVIROLINE	Provides indexing and abstracting coverage of more than 5,000 international primary and secondary source publications reporting on all aspects of the environment. Literature covered includes periodicals, government documents, industry reports, proceedings of meetings, etc.	DIALOG Information Services, Inc. 3460 Hillview Ave. Palo Alto, CA 94304 (800) 334-2564
COMPENDEX PLUS	Provides abstracted information from the world's significant literature of engineering and technology including 4,500 journals, reports, and books. Subjects include: civil, energy, environmental, geological, and biological engineering.	DIALOG Information Services, Inc. 3460 Hillview Ave. Palo Alto, CA 94304 (800) 334-2564

TABLE 4-1. (CONT.) DATA BASES USED TO IDENTIFY ENVIRONMENTAL RESTORATION TECHNOLOGIES IN GERMANY

Database	Description	Contact
BNA Daily News	Includes complete text of the following publications: Environment Daily, Health Daily, Patent, Trademark and Copyright Law Daily, and Toxic Law Daily.	DIALOG Information Services, Inc. 3460 Hillview Ave. Palo Alto, CA 94304 (800) 334-2564
TEXTLINE	Provides access to full-text and abstracted articles from hundreds of international and regional newspapers, magazines, trade journals, and newswires. Includes access to publications originating in Europe.	DIALOG Information Services, Inc. 3460 Hillview Ave. Palo Alto, CA 94304 (800) 334-2564
ULIT	Literature related to the environment and environmental problems in Germany (German with English translation of title).	DATA-STAR D-S Marketing Inc. 485 Devon Park Dr. Wayne, PA 19087 (800) 221-7754

4-2 Waste Management and Environmental Restoration Research and Development in Germany

A significant amount of research and development is spent each year in Germany in the fields of waste management and environmental restoration. About DM 1.5-billion is spent per year for research and development in environmental protection and an additional DM 100-million is spent per year on environmental research projects (USDOC/ITA, 1992). It is anticipated that about DM 400-million will be funded by the Federal Ministry for the Environment in each of 1991 and 1992 on projects to demonstrate environmental cleanup technologies (USDOC/ITA, 1992).

The Federal Minister for Research and Technology (Bundesministerium für Forschung und Technologie, BMFT) is the primary funding agency for research and development in the fields of waste management and environmental restoration. BMFT first outlined its plan for research and development related to environmental policy in the program "Environmental Research and Environmental Technology, 1989-1994" (BMFT, 1989). The program, summarized in Table B-3 of Appendix B, addresses needs related to waste management and environmental restoration. The Minister assigned special status to the environmental restoration area and commissioned research to cover the entire sequence of locating and assessing sites contaminated with hazardous waste, providing safeguard measures until remediation measures are carried out, and remediating and monitoring of the site. Priority was initially given to developing safeguard techniques to prevent emissions from abandoned hazardous sites. The current emphasis is on developing new or improved remediation processes to replace safeguarding processes to an ever increasing extent.

The BMFT provided grants totaling DM 471 million in the field of waste management and environmental restoration during the period from 1976-1988 (BMFT, 1991b). During the last five-years of that period, the funding from BMFT was more than twice the amount contributed by all other federal ministries, with annual funding levels increasing by about 10% each year (BMFT, 1989). Of the DM 471-million, DM 84 million was used to fund 94 technology development programs related to the remediation of abandoned hazardous waste sites. Information on the projects sponsored, and in some cases managed, by the BMFT is available in BMFT (1991a) with updated information (in German) in the UFOR database. In addition to funding technology development, BMFT also funds basic research projects investigating the fundamental processes involved.

The breakdown of funding for the remediation technology projects is shown in Table 4-2. Approximately 60% of the funding supported technologies in three technology areas: waste encapsulation (21%); thermal treatment (19%); and biological treatment (18%). From the point of environmental protection, the remedial measures should be given preference over the safeguarding measures because the safeguarding measures (e.g., the construction of base, side and surface barriers around a contaminated site) do not alter the potential risk constituted by the hazardous materials at the site. However, the safeguarding measures serve to gain time until remediation procedures can be carried out and often offer the most practical method of quickly eliminating the environmental risk, albeit only temporarily. This is particularly true when, as in Germany, there are a large number of contaminated sites and limited federal, state, and local budgets for addressing them.

There are 13 national research establishments in the Federal Republic of Germany that perform research in the areas of waste management and the environmental restoration of hazardous waste sites. Four of these establishments allocate considerable portions of their budgets in these areas:

- Gesellschaft für Biotechnologische Forschung (GBF) — biological remedition;

TABLE 4-2. DISTRIBUTION OF ENVIRONMENTAL RESTORATION PROGRAMS FUNDED BY THE BMFT FROM 1977 TO FEBRUARY 1988

Type of Research and Development	No. of Projects	Percent Funding
Remediation Processes	**33**	**43.9**
Thermal Processes	8	19.1
Biological Processes	15	18.1
Extraction Processes	3	3.0
Combined Processes	7	3.7
Safeguarding Measures	**19**	**22.8**
Stabilization	2	1.6
Encapsulation	17	21.2
Treatment of Secondary Products	**19**	**16.5**
Gas Purification	3	5.8
Seepage water purification	16	10.7
Other Areas	**23**	**16.9**
Recording and Assessment	4	3.0
Site Investigation	16	13.0
Monitoring	3	0.9

(Ref. BMFT, 1991b)

- Gesellschaft für Strahlen- und Umweltforschung mbH (GSF) — underground waste disposal, disposal processes, and the examination of chemical processes in waste;

- Forschungszentrum Jülich GmbH (KFA) — thermal waste treatment; and

- Kernforschungszentrum Karlsruhe GmbH (KfK) — thermal waste treatment and expert systems for risk assessment;

In addition, there are numerous research programs underway at various universities and technical institutes throughout Germany. For example, 45 waste management/environmental restoration projects were finished or initiated by September 1991 at the University of Karlsruhe.

4-3 German Environmental Restoration Technologies

A variety of technologies are available for environmental restoration in Germany. This section identifies both "standard practice" technologies and those that were considered new or innovative. Because of the large number of technologies identified in the search, summary information concerning the new or innovative German environmental restoration technologies has been provided in tabular form.

There is a wide variety of standard practice technologies for environmental restoration in Germany. A list of the more common technologies is provided below.

- Site Characterization — typically accomplished with vertical surface drilling to recover soil, groundwater, and contaminant samples. Also provides access for monitoring and testing activities.

- Containment of Waste on Site — includes installation of cutoff walls, covers, and seals. Often performed to contain waste until a site can be remediated or to contain residual waste after treatment.

- Waste Stabilization — chemicals or grout materials are injected or mixed with contaminated soil that are left in place or removed for disposal.

- In Situ Treatment of Organics — there are over 60 suppliers and process designs for microbial degradation of organic contamination in soil in situ.

- Waste Treatment — includes a variety of methods for removing the waste from soil and liquids:

  - Thermal treatment, i.e., incineration (direct heating) and pyrolysis (indirect heating) in stationary, transportable, or mobile plants with various enhancements. Fourteen companies and eleven thermal treatment facilities were identified.

  - Soil washing, primarily in transportable or mobile plants with various enhancements. Twenty-three companies were identified.

  - Chemical processes for extracting contaminants from liquid waste, including precipitation and flocculation.

  - Electrical processes for extracting contaminants from gases (including exhaust from thermal treatment facilities), e.g., ion exchange.

- Waste Disposal — there is a general obligation to dispose of waste only in permitted facilities containing a liner and a gas/leachate collection system. A geologic disposal facility in an old potash mine is used for hazardous waste disposal. A similar facility was used for radioactive waste storage in eastern Germany prior to unification.

- Site Monitoring — includes periodic sampling and analysis of groundwater wells, air, flora, and fauna. Used to monitor contaminated, remediated, and landfill sites.

Tables 4-3 to 4-9 contain summaries of the innovative technologies identified in the study. The information is arranged by the waste management and environmental restoration categories identified in Section 4-1. A separate table is provided for the technologies in each of the categories with the exception of the first two and the last categories, (waste generation/minimization, waste characterization, and site monitoring), which were not included because the first two areas are outside the scope of this report, and no innovative technologies were identified for the last area.

Each of the technologies is described in the following terms:

- name;
- brief description;
- developer/owner;
- status; and
- reference.

Few of the technologies identified are unique to Germany. The rapid transfer of information via journal articles, symposia, etc., and the large market in environmental restoration has resulted in technologies being fairly ubiquitous. Government research organizations often have cooperative research areas with their counterparts in other countries sharing ideas and breakthroughs. The companies and institutions developing technologies that are really new and promising are unlikely to divulge information until their product is mature enough to bring it to market.

The greatest potential for uncovering technologies significantly different from those available in the US or other western countries is in the former eastern block countries. Trade and technology barriers that were present until only recently would likely result in a different evolution in approach and technology. However, the low priority assigned to environmental problems in eastern block countries in the past raises the question whether a significant effort has been given to developing such technologies.

4-4 Additional Information

In the course of performing the literature and database searches, a considerable amount of related information was collected that, while not entirely germane to the study, provides useful information relevant to environmental restoration technologies or programs. This information has been compiled in several tables in Appendix B. A brief description of the information in each table is provided below:

Table B-1: Recent Case Studies in Germany

The table contains 21 case studies of recent environmental restoration projects in Germany. The projects provide a representative cross section of the types of remediation programs performed in Germany. The technologies used are fairly standard, but some innovative applications were performed. Each project is described in terms of:

- project name and location;
- type(s) of contaminants (if known);
- remediation technologies employed; and
- reference.

Table B-2: BMFT Funded Projects (1984-1990)

Table B-2 contains a list of all of the waste management and environmental projects funded by the BMFT during the period 1984 to 1990. The projects are grouped by the general categories such as the type of treatment (e.g., in situ remediation, safeguarding), process involved (e.g., thermal, biological) etc. Additional information can be found in BMFT (1991b).

Table B-3: Areas of Future BMFT-Sponsored Research and Development in Environmental Restoration

Table B-3 contains a list of the specific areas in environmental restoration in which the BMFT plans to support research and development in the next several years. The list was compiled from BMFT publications, primarily BMFT (1989).

Table B-4: Useful Addresses and Phone Numbers

This table contains an extensive list of agencies, institutes, publications, etc. associated with environmental matters or research in Germany.

Table 4-3. INNOVATIVE WASTE TREATMENT TECHNOLOGIES

Technology	Description	Owner	Status	Reference*
Uranium biosorption	Uses biosorbents in an on-site flow-through bioreactor system to treat uranium contaminated water, either from waste stream or contaminated water from site (surface or groundwater, e.g., uranium mill tailings).	KFA, Jülich	Field testing. Ongoing cooperation with Oak Ridge National Laboratory, TN.	DuCharme et al., 1992.
Bioreactors for volatile chlorinated hydrocarbons	Specific bacterial cultures are used in fixed bed bioreactors (analogous to sand filters in water works or activated sludge reactors) to degrade volatile hydrocarbons in groundwater. Tetrachloroethylene can be degraded if it is first reduced to cis- 1,2-dichloroethylene, e.g., in a fixed bed reactor with methane as the primary substrate and an insufficient oxygen supply.	Institute für Mikrobiologie der TU Braunschweig, Biozentrum	Field testing	Kästner, M., "Biodegradation of Volatile Chlorinated Hydrocarbons," Dechema Biotechnology Conferences 3 - VCH Verlasgesellschaft 1989, p. 909-912.
Biological treatment of contaminated soil and waste water.	Thermal techniques might be used to remediate fine grained soils (bigger than 70 µm), which are very difficult to remediate because of the high cohesion forces and diffusion resistivities. Two test devices are being developed using a biological remediation method. The first one uses an aeroical suspension reactor for the remediation of organically contaminated fine grained soils. The second device for the decontamination of water uses cyclic active cox or sand filter.	Technische Universität Berlin, Fachereich 10 Verfahrenstechnik, Institute für Chemieingenieurtechnik, Berlin	Field testing (DM 387020, Aug. 01, 1989 - Aug. 31, 1991)	UFORDAT, 1992 (BMFT research: Wiesmann, U., Prof.Dr.-Ing. Brauer, H., Prof.Dr.-Ing.)
Biological treatment of soil-wash water and contaminated groundwater with immobilized bacteria.	Uses a four-step reactor. The first step is a cyclical airlift suspension reactor. The second step is an isolated bacteria reactor with active cox and sand as isolation substance. The third step is cyclical reactor for separation of the remaining contaminants. The fourth step is again an isolated microbiological reactor. The reactor was tested with synthetic waste water with methylised and chlorinated phenols, as well as with contaminated groundwater from a waste site. Most of the contamination was remediated during the first two steps. Separation of the remaining contamination and an ozone enrichment during the third step enhanced remediation during the fourth step.	Technische Universität Berlin, Fachereich 10 Verfahrenstechnik, Institute für Chemieingenieurtechnik, Berlin	Laboratory Analysis (DM 147330, Aug. 17, 1990 - Aug. 31, 1991)	UFORDAT, 1992 (BMFT research: Wiesmann, U., Prof.Dr.-Ing. Brauer, H., Prof.Dr.-Ing.

Table 4-3. (Cont.) INNOVATIVE WASTE TREATMENT TECHNOLOGIES

Technology	Description	Owner	Status	Reference*
Microbiological reactor for remediation of contaminated soils	The reactor is built to remediate especially PCB contaminated soils. The contaminated soil is deposited on three fields in a closed hall with a total capacity of 7125 m^3. The soil is sprayed with microorganisms rich water (Patent BASF Lacke+Farben AG). The environmental temperature is between 20 and 42° C. At the same time, warm air is injected through the soil. The air in the hall is remediated with an active carbon filter. The remediated soil can be used for street construction or other purposes.	Bodensanierung Muenster, Muenster	Field testing (DM 3451100, Oct. 01, 1991 - Jul. 31, 1993)	BMFT 1992 (BMFT research: Balthaus).
Remediation of soil contaminated with organic chemicals by composting with straw and special fungi	Straw is innoculated to develop a white-rot fungus substiate. The material is mixed with soil contaminated with aromatic hydro-carbons, dioxins and pesticides. The contaminants are decomposed by the fungus into non-toxic byproducts.	Universität Göttingen Institute für Forstbotanik Wilhelmsplatz 1 3400 Göttingen	Large-scale test successfully complete. 50% of the polyaromatic hydrocarbons in 80 tonnes of soil (8mg/kg) were decomposed. Good decomposition rates have also been achieved at laboratory-scales for dioxins and pesticides.	Projektträgershaft Abfall wirtshaft und Altlasten-Sanierung, Vorhaben 1884-1990; Projektträger: Umweltbundesamt, Mai 1991.
Glass melter sensor technology	Characterize chemistry of waste glasses in melter, for quality control and to protect melter. Conducted real time, in-stream. Determines melter oxidation/reduction state (redox) and glass composition (by determining transition metals content and the total alkalinity of the melt).	HVG (patent)	Field testing. Ongoing cooperation with Westinghouse Savannah River Company, Aiken, SC	DuCharme et al., 1992.
Solidification of low-level radioactive waste with microwaves	Microwaves are used to dry and solidify (and thus minimize the volume of) radioactive liquid wastes of variable composition produced by nuclear research centers, nuclear power plants and reprocessing plants.	Kraftanlangen AG, Heidleberg, West Germany	Field testing stage (completed facility)	Best, A. and H. Genthener, "Solidification of low-level radioactive waste with microwaves," Proceedings of the 1989 Joint International Waste Management Conference in Kyoto Japan, Low and Intermediate Level Radioactive Waste Management, v1, p 311-316, ASME, October 1989.

Table 4-3. (Cont.) INNOVATIVE WASTE TREATMENT TECHNOLOGIES

Technology	Description	Owner	Status	Reference*
Vitrification of high-level radioactive waste	A liquid-fed Joule-heated ceramic melter is used in the PAMELA process to vitrify HLW.	Deutsche Gesellschaft für Wiederaufarbeitung von Kernbrennstoffen mbH, Hannover	Operational since 1985, having processed 360 m^3 of liquid HLW, at Mol Belgium. Planned to be adapted to Wackesdorf Reprocessing Plant.	Kuhn, K.D., W. Kunz, and W. Gruenewald, "Vitrification of high-level waste in the FRG - Development and operation of the PAMELA process," Proceedings of the 1989 Joint International Waste Management Conference in Kyoto, Japan, Low and Intermediate Level Radioactive Waste Management, v2, p. 111-117, ASME, October 1989.
Directed thermal treatment of contaminated soils/waste	Contaminated soil is prepared for combustion in crusher and fed into the kiln unit. The kiln consists of the three rotary kiln drums. The first kiln (200-400°C) is used to evaporate most of the pore water. The contaminants are incinerated in the second kiln (1200°C) with a third adjoining kiln for recovering some of the thermal energy. All organic compounds are destroyed. Outlet gas from the kiln unit undergoes treatment to remove dust and toxins, with the discharge meeting exhaust emission standards (TA Luft 1986)	Zublin AG, 7000 Stuttgart 80 (Möhringen), Albstatweg 3	Operational	Franzius et al., 1991.
Indirect thermal treatment of contaminated soil	Contaminated soil is treated in indirectly heated rotary kilns at a temperature of 600°C. The released gases are thermally treated in an afterburner at 1000-1300°C for 1.5 seconds. Acid gas components are neutralized with dry calcium hydroxide.	Ruhrkohle AG/Bergbau AG Westfalen	NA	Franzius et al., 1991.
Vacuum thermal treatment of contaminated soil	Contaminated soil is continuously advanced over vibrated surfaces which are heated to low temperatures, and subjected to vacuum treatment. Mobile plant operates at two-tonnes/hour.	PHYTEC, Düsseldorf	Pilot plant being developed	Franzius et al., 1991.
Thermal desorption of contaminated soil	Contaminated soil is subjected to radiant heat (infrared), which causes thermal desorption and breakdown of pollutants. Transportable plant operates at two-tonnes/hour.	DEKONTA, Mainz	Pilot plant at Ingelheim since 1988	Franzius et al., 1991.

Table 4-3. (Cont.) INNOVATIVE WASTE TREATMENT TECHNOLOGIES

Technology	Description	Owner	Status	Reference*
Chemical extraction of heavy metals from contaminated soils	A chemical mixture is used to mobilize heavy metals and separate them from contaminated soil. The decontaminated soil is washed and dried. The dissolved heavy metals are recovered and reused.	Landesgewerbeanstalt Bayern (LGA), Konstein	Pilot plant at lead contaminated site in Konstein was planned by Bayer and Mourik Umwelttechnik, and is operational.	Chemical Industry, Issue 12, p. 13, Dec. 1, 1990; Franzius et al., 1991.
Chemical extraction of heavy metals from aquatic sediments	Aquatic sediments are treated with acids, and then combined with hydroxide carbonate precipitation to collect heavy metals ("Prof. Müller process"). Mobile plant operates at 260kg/h with 30% solids.	ROM, Hamburg	Experimental plant planned for Hamburg in 1990	Franzius et al., 1991.
Extraction of heavy metals using countercurrent process	Heavy metals are extracted using countercurrent process in multi-stage acid treatment stations.	Siemens, Berlin, Munich	Patented 1988	Franzius et al., 1991.
Extraction of heavy metals by precipitation	Heavy metals are precipitated from acid solution using complex formers.	Sonnenschein, Budingen	Patented 1988	Franzius et al., 1991.
Countercurrent extraction	Highly volatile extraction agents and countercurrent extraction are used with contaminated soil. Mobile plant operating at 5 tonnes/hour.	Rethmann, Selm + Wessling, Altenb.	Pilot plant in Essen and industrial operation since 1989	Franzius et al., 1991.
Contaminated soil stabilization with lignite ash	Excavated contaminated soil (both organic and inorganic), water and filter ashes from a lignite power plant are mixed in a kneading mill, and the mixture is placed in a sealed ground basin where it turns into a monolythic body, immobilizing the pollutants.	Patented process by Heide/Warner	Pilot project at former Consolidation mine in Gelsenkirchen	Ebel, W. and C. Weingran, "Experiences, Problems and Possible Solutions for a Redevelopment of Contaminated Industrial Sites," in Wolf et al., (1988), p. 495-503.
Soil mixing with ash	Contaminated soil is excavated and thoroughly mixed with a homogeneous ash mush made on site (specific recipe depending on soil analysis), where the ash is sulfate rich and from brown coal power plants. The ash mush adsorbs hydrophobic substances, fixes soluble heavy metal salts by transformation (e.g., into hydroxides), and creates a low conductivity ($<10^{-8}$m/s) matrix.	Tiefbau H. Becker Umweltschutz GmbH, Bottrop (under license)	Field test (former mining ground in Ruhr area)	Höfer, U., "Application Technique for Safe Fixing of Coking Residues on the Basis of a Stabilization Process According to "Heide-Werner," and the First Results on the Behavior Regarding Elution," in Wolf et al., (1988), p. 957-965.

Table 4-3. (Cont.) INNOVATIVE WASTE TREATMENT TECHNOLOGIES

Technology	Description	Owner	Status	Reference*
Ceramic encapsulation of contaminated soils and sludges including heavy metals and organic compounds	Immobilization of contaminants in soils from remediated sites or municipal sludge by incorporating the material in ceramic tiles/bricks.	Ziegelwerk Anton Grehl Birkenstraße 15 7901 Hüttisheim- Humlangen Baden Württemberg	Laboratory phase successfully completed. Contaminants were immobilized and withstood nitric and hydrochloric acid leaching. Large-scale program delayed over environmental concerns over exhaust gases.	"Waste Economics and Site Remediation Projects Supported by the Federal Environment Department from 1984-1990," 7th Edition.
Landfill gas treatment	Remove sulfur, hydrogen-sulfur and hydrocarbons from landfill gases by biofilters and by burning flare, high-temperature flare or fluidized bed reactor.	BMFT	Full scale plants to remove hydrogen sulfide are operational at Gerolsheim	Gesellschaft zur Beseitigung von Sonderabfällen in Rheinlandpfalz, Universität Stuttgart, Ingenieurgesellachaft für Umwelttechnologie- und Forschungconsulting, "General Program for Research and Development of the Remedial Action Technologies Used for Hazardous Waste Landfills Evaluated at the Landfill Gerolsheim/Rheinland-Pfalz," in Wolf et al., (1988), p. 539-541.
Wet oxidation processing	Supercritical water (above 226 bar and 374°C) is used to solubilize tetrachlorobenzene, pentachorbenzene, and 2,3,7,8-TCDD in contaminated soil.	Dekonta, GmbH, Mainz-Rhine	Laboratory	Roth, R., G. Scholz, and H.-J. Jürgens, "Process for PCDD and PCDF Removal from Contaminated Soil," in Wolf et al., (1988) p. 819-825.

Table 4-3. (Cont.) INNOVATIVE WASTE TREATMENT TECHNOLOGIES

Technology	Description	Owner	Status	Reference*
High pressure soil washing	Contaminated soil is mixed with water and then passed through a high pressure (up to 350 bar) water jet nozzle. The pollutants are separated from the soil and transferred to the washing water due to acceleration, without any active wash substances. Volatile substances are removed due to the partial vacuum produced by the jet. The wash water and air exhaust are subsequently treated.	Klöckner, Oecotect GmbH, Duisburg	Operational - used in Berlin on chlorinated hydrocarbons, polycyclic hydrocarbons, phenols, benzene, mineral oil, lindan, lead and cyanide (130-200DM/t, 15-40t/hr depending on clay content)	Heimhard, H.-J., "High Pressure Soil Washing Process for Cleaning Polluted Soil in Berlin," in Wolf et al., (1988) p. 871-882.
Wet mechanical separation	DECONTERRA process is a multi-stage wet mechanical separation process for remediation of contaminated soil (organics and inorganic compounds). Contaminated soil is excavated, pretreated (crushed and sieved) and mixed with water, and then transferred first to a wet attritioner drum and then to a hydrocyclone to separate the finer particles. Pollutants are either suspended in the liquid or bound to finer (<<1mm) particles, which are separated for subsequent treatment (e.g., flocculation and then incineration or landfill disposal).	Lurgi Metallurgie GmbH/LurgiUmwelt-Beteiligungsgesellschaft (LUB) mbH, Frankfurt am Main (Lurgi Corp, NJ)	Operational	Lurgi/LUB brochures.
Mobile soil washing plant	Two wash cycles are used with mechanized fluidized bed (water and detergents), counter current rinsing, and thermal destruction of residual material. Plant operates at 20 tonnes/hour.	Ed. Zublin AG, Stuttgart	Mobile plant designed in 1989	Franzius et al., 1991.
Leachate evaporation	Two stage acidic-basic evaporation process to separate all salts and pollutants from landfill leachates for subsequent disposal. The first acidic stage separates the organic contents (including ammonium salts). The second basic evaporation stage removes phenols and other inacidic medium volatile components; the light volatile components (e.g., chlorinated hydrocarbons) are removed by vaccum.	Zweckverband Sondermüllplätze Mittlefranken (ZVSMM), Schwabach	Operational at ZVSMM landfills in Schwabach (3.6t/hr, 80-90DM/m^3)	Schoder, F., "Disposal of Leachate by Evaporation," in Wolf et al., (1988) p. 939-941.
Sodium treatment of organic liquids	Sodium is mixed with organic liquids to destroy organic compounds containing halogens, especially chlorides (e.g., PCBs, PCDDs, or PCDFs) by ion exchange, and then the resulting sodium salts (sodium chloride) are separated.	Degussa AG, Hanau	Laboratory	Bilger, E., "Detoxification of Organic Liquids using Sodium/Dehalogenation of Harmful Substances," in Wolf et al., (1988) p. 943-945.

Note: * References are completely specified or contained in Section 5, References.

Table 4-4. INNOVATIVE WASTE TRANSPORTATION/STORAGE TECHNOLOGIES

Technology	Description	Owner	Status	Reference*
Roof covering operating waste landfills	A roof without intermediate supports (up to 300m span) and which can be shifted in the longitudinal direction is used to cover the landfill area where dumping is occurring, thus reducing percolation of precipitation. Once dumping in the area has been completed and the surface sealing system installed, the roof can be shifted to the next dumping area. Could also be applied as a temporary cover until a permanent one is installed.	Bilfinger+Berger Bauaktiengesellschaft and MERO-Raumstruktur (Würzburg)	Mature	Gossow, V., "The Refurbishment of Contaminated Sites and High Safety Waste Dump Technology," in Wolf et al., (1988) p. 601-608.

Note: * References are completely specified or contained in Section 5, References.

Table 4-5. INNOVATIVE SITE CHARACTERIZATION TECHNOLOGIES

Technology	Description	Owner	Status	Reference*
Remote contaminant sensor technology	Sensors for characterizing the chemistry of organics, toxic materials, and actinides in situ or in waste process stream by adsorption spectroscopy using optical sensors for detection of heavy metals and near-field thermal lensing.	KfK, Karlsruhe	Ongoing cooperation with Lawrence Livermore National Laboratories, Livermore, CA.	DuCharme et al., 1992; R. Silva, ITEP Monthly Progress Report, July 1992.
Internal Reflection Spectrometer	A portable system for quantitatively detecting toxic organics (e.g., TCE) in wells.	KfK, Karlsruhe	Field testing ongoing.	DuCharme et al., 1992; R. Silva, ITEP Monthly Progress Report, July 1992.
Laser-based contaminant sensor	Uses a photomultiplier to detect the light pulse which is produced by the electrical breakdown occurring when colloids are present in a solution and are intersected with a focused laser beam.	KfK, Karlsruhe	Laboratory testing ongoing.	DuCharme et al., 1992; R. Silva, ITEP Monthly Progress Report, July 1992.
Using easily measured mercury concentrations as an indicator of contamination	Mercury has a distinct migration and enrichment behavior which can be exploited to identify likely areas of contamination. Shallow (1m) soil samples are analyzed by flameless atomic adsorption spectroscopy.	PanGeo - Geowissenschaftliches Büro and Institut für wassergefahrdende Stoffe, Berlin	Demonstrated in field	Appel, D. and M. Pöppelbaum, "Mercury (HG) - New Ways for an Old Pathfinder," in Wolf et al., (1988) p. 235-237.

Note: * References are completely specified or contained in Section 5, References.

Table 4-6. INNOVATIVE WASTE DISPOSAL TECHNOLOGIES

Technology	Description	Owner	Status	Reference*
Advanced liner technology	Includes: design, monitoring and construction of engineered surface barriers and covers for landfills; remediation of landfills using liner replacement systems; stabilization of landfills (especially highly corrosive wastes), using in situ treatment equipment and materials.	University of Karlsruhe, Karlsruhe	Field testing. Onging cooperation with Westinghouse Hanford Company, Richland, WA.	DuCharme et al., 1992.
CONTREP base sealing system	A dump area is divided into individual fields measuring 50x50m, within each of which an enclosed sealing body is formed by connecting the upper to lower sealing membrane. Each individual field is inspected by creating a pressure lower than atmospheric. Any subsequent damage (e.g., to the upper sealing membrane due to chemical stresses and strains from the dumped waste) can be easily detected by the inspection drainage pipes incorporated in the gravel layer between the membranes, and "repaired" by grouting the gravel layer (e.g., with a bentonite-cement, clay powder).	Bilfinger+Berger Bauaktiengesellschaft and BASF, patented with licenses available	Field demonstrated at Flotzgrün refuse dump near Speyer in 1986/1987	Gossow, V., "The Refurbishment of Contaminated Sites and High Safety Waste Dump Technology", in Wolf et al, (1988), p. 601-608. Krubasik, K., "Safer Sealing Systems for Waste Dumps," in Wolf et al., (1988) p. 609-611.
In situ solidification of liquid, low and intermediate level radioactive wastes	Technology used at 500m deep underground repository in salt caverns at Morsleben to dispose of low and intermediate liquid radioactive waste in former East Germany, by mixing with lignite ash (1:3 ratio)	Brunn Leuschner Nuclear Energy Kombinat	Mature.	Varley, J., "Handling Low and Medium Active Waste in East Germany," Nuclear Engineering International, v. 35, no. 434, p. 40-42, Sept. 1990.
High security disposal facilities	Standard landfills or silos with composite bottom liners and covers are constructed on top of a concrete vault which provides access for monitoring any repair of the bottom liner.	Ed. Züblin AG, Stuttgart	Conceptual.	Züblin brochure.

Note: * References are completely specified or contained in Section 5, References.

Table 4-7. INNOVATIVE IN SITU TREATMENT TECHNOLOGIES

Technology	Description	Owner	Status	Reference*
In situ VOCs destruction	In situ groundwater treatment wells (recirculation) in conjunction with treatment processes (e.g., bioremediation, physiochemical).	University of Karlsruhe, Karlsruhe	Field Testing. Ongoing cooperation with Oak Ridge National Laboratory, TN.	DuCharme et al., 1992.
Microbial degradation of polycyclic aromatic hydrocarbons in contaminated soil.	Percolation machines and laboratory fermentation devices are used to analyze the degradation of oil products, including the toxicity of the end products (mutation analysis of the bacteria under the appropriate toxical conditions). The problem of rest saturation of contaminants in soil will be analyzed, using anorania such as Phosphor or Bioemulators.	Universitäet Karlsruhe, Deutscher Verein des Gas- und Wasserfaches, Forschungsstelle am Engler-Bunte-Institut, Karlsruhe, BW	Laboratory analysis (DM . 850500, May 01. 1990 - Apr. 30. 1993)	UFORDAT, 1992 (BMFT research: Werner, P., Dr. and Hedden, K., Prof. Dr.)
Bioremediation enhancement with additives	NO_3- or hydrogen peroxide is added to flushing water systems for in situ bioremediation.	PROBIOTEC GmbH, Dueren-Guerzenich	Mature. NO_3- was used as an electron acceptor for cleanup of 30 tonnes of heating oil and aromatics, which took about two years. Similarly, hydrogen peroxide was used as an oxygen source to cleanup $70m^3$ of gasoline (starting in 1987).	Schwefer, H.-J., "Latest Development of Biological In-Situ Remedial Action Techniques, Portrayed by Examples from Europe and USA," in Wolf et al. (1988), p. 687-694.
Bioremediation enhancement with solvents	A nontoxic inorganic solvent (unnamed) is added to the soil to reduce the adsorption of hydrocarbons to the soil (especially clay particles), thus increasing the amount in solution and making them more available to biodegradation. The solvent can subsequently be removed by flocculation.	NA	Laboratory testing	Werner, P. and H. J. Brauch, "Aspects on the In situ and On-Site Removal of Hydrocarbons from Contaminated Sites by Biodegradation," in Wolf et al. (1988), p. 695-704.

Note: * References are completely specified or contained in Section 5, References.

Table 4-8. INNOVATIVE IN-SITU CONTAINMENT TECHNOLOGIES

Technology	Description	Owner	Status	Reference*
Chamber-system sealing walls	Two parallel sealing walls are constructed several meters apart, with transverse bulkheads every 50m connecting the two walls and dividing the walls into individual chambers. A well with a control gauge is sunk within each chamber. By lowering the water level in each chamber below the external water level, the efficacy of each individual chamber can be checked. Potential defects can be detected and repaired with relatively limited expenditure of both money and time.	Grün+Bilfinger Ges. mbH/Bilfinger+Berger Bauaktiengesellschaft	Used to enclose Rautenweg municipal dump in Vienna	Gossow, V., "The Refurbishment of Contaminated Sites and High Safety Waste Dump Technology," in Wolf et al., (1988) p. 601-608. Arz, P., "The Diaphragm Wall Chamber System-Inspection of the Efficacy and Long-Term Observations," in Wolf et al., (1988) p. 613-615.
Construction of subsurface seal below contaminated sites	Relatively standard longwall mining equipment (possibly remote controlled) is used to simultaneously drive two 1m high longwall faces in a vertical V-formation, each face extending from a surface trench on either side of a landfill to a tunnel running the whole length of the site. As each face advances, the void behind it is hydraulically backfilled with a low permeability, low compressibility plastic material (79% sand/gravel, 15% clay powder, and 6% water, with sodium silicate and Dynagrout additives). The central tunnel is constructed by roadheader, with due consideration of potential hazards from contaminated materials. Drainage pipes are installed in the V-cuts to collect seepage, and will be connected to a collecting pipe in the central tunnel which will carry all fluids to a sump from which it can be pumped to the surface for treatment.	Consortium of Preussag Anlagenbau (general contractor), Deilmann-Haniel (tunneling contractor), Paurat and Saargergwerke (longwall operations).	Completed laboratory testing and analysis, field test proposed at Munchehagen (near Hannover).	Chadwick, J., "Longwall to save landfill timebomb?," Mining Magazine, June 1992, p. 340-341.
In situ sealing	In situ containment of contaminants or construction of engineered barriers by injecting wax-emulsion sealants (other than standard cement-based grouts) from boreholes into soil and rock formations.	MIBRAG/DBI, Leipzig	Field testing completed.	DuCharme et al., 1992.

Table 4-8. INNOVATIVE IN-SITU CONTAINMENT TECHNOLOGIES

Technology	Description	Owner	Status	Reference*
Horizontal drilling	Drilling horizontal boreholes in soil and rock formations within or below contaminated zones for characterization, injection/removal, and monitoring. Using microtunnelling equipment with water-jet outer device, a series of horizontal wells were drilled from a central caisson through the contaminated region. Contaminants are collected via slotted liner containing an inner pipe developed by KSK made of a porous PVC material. This combination prevented soil particles from plugging the system. The existing drilling equipment is capable of horizontal boreholes up to 200 m long and 10 m below the surface. Guiding accuracy at 10 m depth is 200 mm. The drilling agent used is bentonite.	KSK S. A. Genf (CH) Niederlassung Rastatt	Field testing. Has been used to remediate two industrial sites, are contaminated with kerosene and the other contaminated with polyaromatic hydrocarbon. Affiliated with UTILX (formerly Flow Mole) in US	DuCharme et al., 1992.
DWR-C Dynagrout - grout additive	Additive to grout (e.g., for cutoff walls) which ensures simultaneous liquefaction and setting delays over longer periods as well as making the mass hydrophobic with suitable rheological properties.	DYNAMIT-NOBEL, Troisdorf	Field tested at Gerolsheim hazardous waste dump in Rhineland-Palatinate	Müller-Kirchenbauer, H., (Institut für Grandau, Bodenmechanik und Energiewasserbau, Univerität Hannover - IGBE), J. Ehresmann (Gesellschaft zur Beseitigung von Sonderabfällen in Rhineland-Pfalz mbH, Frankenthal), J. Rogner (IGBE), W. Friedrich (IGBE), and D. Gremmel (IGBE), "Test Seal Wall for Gerolsheim Hazardous Waste Dump," in Wolf et al., (1988) p. 635-637.
HDPE panel cut off walls	A trench made up to 1 m wide and up to 50 m deep is excavated in (lengths up to 10 m, with bentonite slurry support). Multilayer HDPE and drainage membrane panels are sunk and joined together by means of interlocking claw-like profiles which are welded together.	Ed. Züblin AG, Stuttgart	Field tested.	Züblin brochure.

Note: * Reference are completely specified or contained in Section 5, References.

Table 4-9. INNOVATIVE WASTE REMOVAL TECHNOLOGIES

Technology	Description	Owner	Status	Reference*
In situ cadmium extraction	Hydrochloric acid is used to leach cadmium from contaminated soil in situ. The acid leachate is purified by ion exchange and reused. The treatment cost is about $75/t.	NA	Field demonstrated	Pheiffer, T., T. Nunno, and J. Walters, "EPA's Assessment of European Contaminated Soil Treatment Techniques," Environmental Progress ENVPDI, v. 9, n. 2, p. 79-86, May 1990.
Oil mobilizing surfactant	Specific surfactant (anionic, cationic, ampholtic, or nonionic) are percolated into oil contaminated ground in order to mobilize the oil for subsequent removal.	Battelle-Institute.V., Frankfurt	Laboratory	Hurtig, H.-W., T. Knacker, H. Schallnass, and G. Arendt, "In Situ Mobilization of Residual Oil in Contaminated Soil - Development of a Method for Selecting Oil - Mobilizing Surfactant," in Wolf et al., (1988) p. 921-928.
Hydroshock	Operation of a wave generator suspended inside a water well close to the base of an aquifer produces increased mobilization of contaminants, and thus more effective removal.	Harris Geotechnik GmbH	Field Testing	Holzwarth, "Experiences Joined in the Remediation of CHC-Contaminated Case," in Wolf et al., (1988) p. 935-937.
In situ soil washing with piles	High pressure (500 bar) water jets are sunk in situ using pile driven jacket tubes. Resulting sludge is extracted and microbiologically processed on site. Plant operates at 12t/hr.	Philipp Holzmann AG	Mobile plant operational since 1989.	Franzius et al., 1991.
In situ soil washing with lances	High pressure water jets are sunk on site using injection lances. Contaminated water is extracted and treated on site.	Arge Bodensanierung, (GKN Keller Spezialtiefbau, Hamburg)	Mobile plant operational since 1990	Franzius et al., 1991.
Soil air evaluation method for linear geometry.	Uses two linear drainage systems with peripheral arms: a lower groundwater drainage and an upper soil air drainage. Air flow was achieved through air injection in specially positioned wells.	Stadt Herne, Amt füer Umweltschutz, Herne	Field operation at an old cox plant contaminated with benzol toluol and xylol (DM 5509680, Nov. 01, 1990 - Dec. 31, 1993)	UFORDAT, 1992 (BMFT research: Kueper, J., Dipl.-Geol., Scholz, D., Dipl.-Ing.).

Table 4-9. INNOVATIVE WASTE REMOVAL TECHNOLOGIES

Technology	Description	Owner	Status	Reference*
Extraction of organic substances and heavy metals, using steam or complex components.	Organic contaminants are extracted through high temperature (150°C) steam injection. A decrease of toxicity is expected through the high temperature treatment of the contaminants. The heavy metals are extracted using complex components in a water (or non water) solution.	Technical University Aachen, Institut für Siedlungswasserwirtschaft, Aachen	Laboratory analysis and prototype field testing (DM 1364935, June 01. 1990 - May 31. 1992)	UFORDAT, 1992 (BMFT research: Dohmann, M., Prof. Dr.-Ing.)

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APPENDIX A

EXAMPLES OF CONTAMINATED SITES IN GERMANY

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EXAMPLES OF CONTAMINATED SITES IN GERMANY

This section reviews available information for 15 contaminated sites in Germany. The descriptions are intended to illustrate the extent and nature of hazardous waste management and cleanup problems existing in Germany and include some of the most severe problems encountered. Available information is limited, particularly for industrial sites, because of the level of confidentiality maintained by industry and state regulators.

A-1 Georgswerder Landfill (Hamburg)

The Georgswerder landfill is located about 5 km south of the city center of Hamburg in a former channel of the Elbe River. The site is owned by the City of Hamburg. From 1948 through 1979, the site was an operating landfill. Disposed wastes consisted primarily of residential waste, soil, and construction materials, but also included 200,000 m^3 of liquid and solid special wastes. Between 1967 and 1974, 150,000 m^3 of liquids were deposited in basins that were subsequently filled with residential wastes. Over 20,000 m^3 of drummed materials from industrial and commercial sources were deposited in four designated areas. The landfill ceased accepting waste in 1979. The site area is 44 ha, and the current waste volume is about 7 million m^3.

The Georgswerder landfill has contamination problems stemming from mobility of disposed chemicals and leachate compounded by an ineffective cover and base, which allow significant seepage and infiltration of precipitation.

Site investigations were initiated following the detection in 1983 of the dioxin 2,3,7,8-TCDD in the oily component of leachate flowing from the side of the landfill. Site investigations were performed from 1984 through 1988. Evaluations of conditions in the vicinity of the landfill were performed, including the extent of contamination in surface water, groundwater, soil, air, animals, and vegetation. During this period, preliminary planning of contaminant treatment methods was undertaken, including leachate control measures and landfill sealing.

During site investigations, chlorinated and unchlorinated organic compounds were detected, particularly in the oily components of leachate outflows. Typical values for the oil phase in a leachate oil/water separator were: 27,000 mg/kg chlorobenzene; 130 mg/kg PCBs; 12,000 mg/kg aromatic solvents, 35 mg/kg volatile chlorinated solvents; and 0.032 mg/kg 2,3,7,8-TCDD. Typical values for water in the leachate/oil/water separator were: 200 mg/l sulfate; 2,000 mg/l chloride; 3,000 mg/l ammonium; 1 mg/l aromatic solvents; and 0.1 mg/l volatile chlorinated organics.

Despite the high infiltration through the cover and concerns about migration through the unlined base of the landfill, relatively little inorganic impact on underlying groundwater was detected. Average increases of 0.003 mg/l above the upgradient values were found for aromatic solvents and for volatile chlorinated organic compounds.

A remediation concept was agreed to in 1985. The plan included construction of a low permeability cover, extraction and incineration of landfill gas, collection of leachate discharges for physical and chemical treatment, and preparation of plans for groundwater control measures if proved necessary. Plans also called for the excavation of some of the most contaminated material for disposal elsewhere or for high temperature incineration. The cover design considered two zones, upper and lower, to take account of the observed leachate outflow locations and of the resulting contamination potential during construction. The upper zone was constructed first. Gas collection and water treatment systems have been constructed, but cover construction is still in progress.

Estimated remediation costs included DM 23-million for capping of the upper zone (16 ha), DM 75 million for capping of the lower zone (29 ha), and a total estimate of DM 150-million.

Sources: (Zeitschrift Wasser und Boden, 1989) (Umweltbehorde Hamburg, 1988)

A-2 Müggenburgerstraße Landfill (Hamburg)

The Müggenburgerstraße landfill is located about 6 km southeast of the city center of Hamburg in a marshy area covering approximately 5 ha. Between 1963 and 1967, solid and liquid wastes were placed at the site, owned at that time by the City of Hamburg. No liner or low permeability materials were present at the base or sides of the disposal area. Disposed wastes included construction and demolition wastes, port and industrial wastes, waste oil, chemical production residues, dioxin contaminated material, oil residues, and solvents. Liquid wastes were discharged into basins and then covered with solid waste materials. In 1967, the land was acquired by Norddeutsche Affinerie AG, and covered by a 0.5 m layer of soil. Current ownership is unclear, but the City of Hamburg is handling site remediation.

Dioxins were identified at the site in 1984, and a systematic site investigation began in 1985 with installation of 200 measuring points, including groundwater observation wells, driven probes, and gas probes. Approximately 2,000 samples were taken and over 50,000 analytical results obtained. The soil at the site was determined to be a 15-m thick sand unit underlying the organic rich wetland soils. Most of the landfill area was determined to have organic compounds at concentrations above the Dutch list C values. Soil gas samples taken in the oil basin area indicated the presence of aromatic solvents and chlorinated organics. Groundwater outside the landfill area has been contaminated with waste compounds. Lead and arsenic were detected in one area.

Planned remediation measures included capping of the landfill and cutoff wall construction, to be followed by removal for treatment and disposal of liquid and solid wastes.

Sources: (Franzius, et al., 1992)

A-3 Altwarmbüchen Landfill (Lower Saxony)

The Altwarmbüchen landfill is located approximately 10 km northeast of Hannover (Lower Saxony), adjacent to the intersection of the A2 and A7 autobahns. The site has been used by Hannover since 1937 as a waste disposal site. The 60-m high landfill contains approximately 9 million m^3 of waste.

No information is available on the history of site investigations at this facility. However, the concentration of hazardous chemicals is reported to be ten times higher than the average for domestic waste landfills. The annual inflow of rainwater into the landfill is estimated to be 20,000 m^3, and no systems or liners for reduction of leachate outflow exist.

Planned remediation includes leachate pumping, scheduled to start in 1993. Investigations are under way for installation of a 6-km-long cut-off wall. The estimated cost for the 96,000 m^2 cutoff wall is DM 40 million.

Source: (Hannoverschen Allgemeinen Zeitung, 1992)

A-4 Münchehagen Landfill (Lower Saxony)

The Münchehagen landfill is a special waste disposal site located near the village of Loccum, approximately 25 km south of Nienburg (Lower Saxony). Firma Börstinghaus und Stenzel operated the site from 1968 to 1973. This company has since been declared bankrupt, and their portion of the landfill is now known as Altdeponie Münchehagen. Deponie der Gesellschaft für Sondermüllbeseitigung (GSM) operated the site from 1977 to 1983, and has since been declared bankrupt. Current ownership is not known. The site was apparently not operated from 1973 to 1977 or since 1983.

The site contains two adjacent disposal areas:

- The disposal area used by Altdeponie Münchehagen has a surface area of 2.5 ha, with 25 individual pits ranging up to 6-m deep and a total content of approximately 50,000 m^3 of industrial wastes, which would presumably now be considered special waste.

- The disposal area used by GSM has a surface area of 5.25 ha with 3 pits excavated to a depth of up to 25 m in claystone and a total content of approximately 350,000 m^3 of special wastes.

Site investigations have been performed since 1985 and include gas emission measurements, vapor probe sampling in the Altdeponie area, soil sampling from surrounding areas, and detailed evaluations of the geology in the vicinity of the landfill. Observations at the site include an oily streak seen on a separator dam between two pits in 1985. Analysis of this material yielded a dioxin (2,3,7,8-TCDD) content of between 1,125 and 560 µg/kg. Total organic halide compounds were also detected.

Risk assessments have been made based on the site investigations. The Münchehagen landfill is considered to have a high risk potential because infiltration, leachate production, and contaminant migration are poorly controlled. Wastes have migrated through the thin, 0.6-m to 1-m thick clay cap. Outflows of highly contaminated leachate have been observed, and groundwater contamination has been reported.

Some remediation has been performed at the site. In 1980, 5-m deep clay barriers were constructed to restrict the outflow of leachate from the landfill. Since 1983, leachate from the landfills has been transported to a treatment plant. The treatment plant is 30 km away and uses a biological process. The sludge was kept separate and disposed of separately from the normal waste water materials. After the discovery of dioxin in 1985, it was considered to be necessary to provide physical and chemical treatment at the site as a pretreatment for the biological process. In 1985 and 1986, two areas in danger of collapse were drained and filled with claystone. In 1990, drains were placed and a membrane cap was constructed. Costs of remediation between 1985 and 1987 totaled DM 35.5 million.

In 1987, a plan for long-term containment of the landfill was developed. The plan included cutoff walls, deep sealing using grout, capping, and various hydraulic, leachate, and gas control measures. The estimated costs of these measures were DM 80-million.

Source: (Hösel et al., Undated)

A-5 Grube Merkel/Gifhorn (Lower Saxony)

This site is a former sand quarry located in Gifhorn, about 30 km north of Braunschweig (Lower Saxony). From the mid-1970s, residential and commercial wastes were brought to the site. The waste-filled pit covers an area of approximately 15,000 m^2. The base of the pit was 8-m below ground level and 3-m below the water level in the sand.

Waste materials brought to the site included galvanizing sludges, oil- and solvent-contaminated soil, solvent-containing waste oil, fabrics with paint residues, and building wastes. It has been estimated that 200 to 450 m^3 of waste oil was placed in the pit, with 23t of chlorinated organic compounds and up to 9 kg of PCBs.

A downward hydraulic gradient exists from the upper, contaminated aquifer to a lower aquifer that serves as a drinking water source. However, a thick aquitard separates the aquifers and may result in low groundwater flow volumes between the aquifers.

Elevated chlorinated organics levels were found in the groundwater flow and in naturally vegetated soil around the deposit. The maximum detected concentration was 11,250 ppm. In groundwater moving away from the site, the sum of concentrations of individual organic contaminants measured with a gas chromatograph was greater than 700,000 µg/l.

Site remediation began in 1991 and involved oil recovery, downgradient pumping of groundwater, and a cutoff wall. Two oil removal wells were constructed, and the water table was lowered a few tenths of a meter. Two groundwater extraction wells were used to remove groundwater for treatment. Water treatment was multi-stage and included oil/water separation, pH adjustment, air-stripping of the volatile organic compounds with an activated carbon filter for the off-gas, biological breakdown of high molecular weight compounds in the water, and filtration. A double cutoff wall was constructed by driving sheet piling, then removing the piling and grouting up the void made by the piling.

Source: (Franzius et al., 1992)

A-6 Bielefeld-Brake Landfill (North Rhine-Westphalia)

This site is a former clay quarry filled with wastes, located in the Brake district of the City of Bielefeld (North Rhine-Westphalia). The current site owner is the City of Bielefeld. The quarry was filled with industrial sludges, domestic waste, and building rubble during an unspecified period. An estimated 24,000 m^3 of industrial sludges and 10,400 m^3 of domestic waste were emplaced. The wastes reportedly had high metals content, high concentrations of volatile organic compounds, and PCBs at concentrations up to 15 g/kg. The total estimated volume of sludges, domestic waste, and building rubble is 121,000 m^3. In 1971, a building development plan was approved for the landfill area and surroundings, with knowledge of the previous use. In 1979, a housing development was constructed in the area. In 1983, sludges were found during foundation work for a house.

A series of epidemiological investigations of local residents (600 adults and 150 children) was performed in 1984. In 1987, additional investigations were performed, including analyses of sludges, landfill material, soil, groundwater, and landfill gas. Following the epidemiological studies, it was concluded that there was some health impairment for local residents based on the frequency of abnormal transaminase values, and there was a suspicion of exposure to hazardous materials from the former landfill. However, further studies concluded that hazardous chemicals could only reach human receptors through the air pathway. Investigations of chlorinated organics showed no clear exposure pathway because detected concentrations were low in comparison to permitted levels.

In 1987, a proposal to control the landfill was accepted. Proposed remedial measures included surface capping and drainage, gas extraction, groundwater lowering and leachate disposal, and surface shaping. The measures were intended to be carried out between 1989 and 1991.

Estimated remediation costs included DM 3 million on investigations and planning before remediation work was initiated, DM 20 million for costs for damages and purchase of the houses in the landfill area, and DM 25 million for actual remediation costs.

Source: (Franzius et al., 1992)

A-7 Prael Landfill (Rhineland-Palatinate)

The Prael landfill is an industrial waste disposal site located near Sprendlingen (Rhineland-Palatinate). The site was formerly a quarry for brick material covering approximately 10 ha. In 1966, a permit was given to Prael for disposal of 700,000 m^3 of industrial residues, considered to be sandy or earthy material without odor. However, in 1968, it was determined that other types of waste had also been placed at the site, including glue and bitumen residues, tarry sludges, oily treatment sludges, resin and plastic residues, acids and liquid residues. Despite a prohibition, disposal continued until 1971. An estimated total of approximately 450,000 m^3 of wastes was placed at the site. In 1974, it was determined that about 100 tonnes of cyanide-containing salt complexes, residue from hexachlorocyclocyclane production, solvents, cresol, trichlorophenol, drug residues, PCB-contaminated waste, heavy metals, and chlorinated organics were emplaced.

In 1980, investigations of shallow water were started by the state government of Rhineland-Palatinate. From 1982 to 1984, further investigations were undertaken involving additional borings, groundwater monitoring wells, and geophysical measurements. The investigations indicated that some contaminated wastes were deposited outside the actual landfill area. It was also determined that the base of the landfill consisted of a 1-to-2-m thick permeable layer. Infiltrating water was building up in the waste and outflows were in a direction flowing under the adjacent town. Groundwater from above the clay stratum showed high contaminant levels, including chloride at over 10 gm/l, phenol at over 100 mg/l, and chlorinated volatile organics at several 10's of mg/l. Contamination was detected beneath the town, but it was not possible to confirm whether this came from the landfill because the water quality was not potable prior to landfilling.

In 1979 and 1980, remedial actions were implemented including construction of a clay cover and a leachate collection shaft, drains, and a pond. In 1985, approval was granted for the second phase of remediation, including sealing of the upper surface of the landfill and revegetation, construction of leachate extraction wells, holding tanks, and a biological and carbon absorption treatment facility, and an upgradient cutoff wall. The materials used in the cutoff wall are not known, however.

Costs for remediation were estimated at DM 3.0 million for the preliminary measures and investigations up to 1984, plus leachate treatment and monitoring to 1987, DM 1.4 million for remediation investigation and planning, and DM 13.1 million for implementation of final remediation.

Source: (Franzius et al., 1992)

A-8 Hirschhagen (Hesse)

Hirschhagen is the site of a World War II munitions production plant, located in northeast Hesse about 25 km southeast of Kassel near the town of Hessisch Lichtenau. Beginning in 1939, the Dynamit Nobel-Actien Company manufactured high-explosives and was under control of the Montanindustrie (mining) GmbH. Daily production of TNT was 81 tonnes, with daily water requirements of 9 million liters of water. Picric acid was produced at a rate of 2,075 tonnes per year. The site encompasses 233 ha.

Waste water from the plant was piped to the Fulda River. In 1941, a treatment plant was built to neutralize the waste water. From 1943 to 1945, four explosions were reported at the plant. Production ended in 1945, three days prior to Allied entry into Hessisch Lichtenau. Dismantling of the plant occurred in 1946, leaving chemical residue in soil and groundwater. In 1951, the name of the site was changed to Industrieverwaltungsgesellschaft (IVG). In 1966, the site was put up for sale. Approximately 200 ha had been sold by 1970. The railway network had been taken over by Deutsche Bundesbahn by 1970, and that acquisition may account for the additional land area.

Environmental investigations at the site began in 1963, with investigations of areas where high concentrations of TNT were identified. A drinking water analysis was performed in 1964. First confirmation of the influence of a nitrotoluene-related contaminant plume on a water supply well was in 1967, and by 1973 the concentration had risen to 6.7 µg/l.

A borehole drilling investigation with associated soil and groundwater sampling was performed in 1984. By 1986, it was apparent that a large number of contamination sources was present at the site, and soils and groundwater are reportedly contaminated with nitrotoluene, nitrobenzene, nitropentaerythritcyclnite, PCBs, and aromatic aminoes. Pump testing in a deep well installed beneath the site showed only what is described as trace-level contamination (0.01 - 0.03 µg/l of nitrotoluene). In a shallower "middle" aquifer, aromatic aminoes at 20 µg/l and nitrotoluene at 2 µg/l were found. Investigation of the upper aquifer to determine the influence of the waste heap involved drilling 22 boreholes to depths of up to 25-m. The results have been reported as showing strong contamination, with up to 63,300 µg/l nitrotoluene.

Remediation activities include removal and disposal of the contents of sludge basins (133 mg/l of nitrotoluene), cleaning out of the former drainage systems, and planning for the extraction and treatment of groundwater. Public water supply arrangements in the area have also been progressively modified as wells have become affected by contaminant plumes. In one case, water from a well is mixed with that from another source and then treated with an activated carbon filter before distribution.

The Hirschhagen site is located on a hill, apparently in a groundwater recharge area. One concern at the site is that an initial proposal to pump from the lower aquifers to eliminate the possibility of migration of the contamination into the lower aquifer may in fact increase the spread of contamination by increasing the flow from the heavily contaminated upper zone into the lower ones.

Remediation-related costs, including alternative water supply arrangements, were already DM 25 million in mid-1989. In 1990, the total remediation related costs were estimated as DM 70 million.

Source: (Hessisches Ministerium für Umwelt und Reaktorsicherkeit, 1989)

A-9 Malsch Landfill (Baden-Württemberg)

The Malsch landfill is a special waste disposal facility located near Malsch on highway B3 about 20 km south of Heidelberg in Baden-Württemberg. The original owner operated a clay quarrying company from 1920 to 1971. Beginning in 1971, the site was developed as a hazardous waste landfill. In 1974, temporary closure and remedial measures were implemented, including construction of a leachate collection system and installation of groundwater monitoring wells. In addition, improved systems were set up for control and monitoring of wastes brought to the site and for the analysis of leachate and groundwater samples. The landfill was reopened in 1976, and the landfill ownership was taken over by Sondermüllbetriebsgesellschaft (SMB). In 1984, waste disposal at the landfill ceased. The site covers 7 ha, with 5 ha occupied by a landfill containing about 700,000 tonnes of waste.

Wastes reported to have been disposed at the Malsch landfill include:

- salt slags from aluminum recycling;
- metallic hydroxide filter cakes;
- contaminated soils with high mineral oil content; and
- approximately 1,800 tonnes of waste containing dioxin and furans (2,3,7,8 TCDD content ca. 2 kg ; total dioxin content ca. 30 t).

The first phase of site investigations was performed in 1984 and 1985, with a drilling and sampling program. Data from the investigations showed contamination and indicated that several aquifers could be affected by the landfill, but data were insufficient for a complete risk assessment to be made. A second phase of testing occurred in the period 1987-1989, including an assessment of formation fracturing and permeability measurements to define the hydrogeologic regime in the landfill area sufficiently to enable a water balance to be made. The water balance accounted for the presence of multiple aquifers.

Hydrogeologic conditions at the site have resulted in significant leachate production and outflows. Analyses of leachate samples indicated that the leachate was strongly contaminated with approximately 120 organic compounds and salts. The amount of leachate produced was high, averaging 20 m^3/d and rising to 100 m^3/d after heavy rainfall.

Main analytes in the leachate were: chemical oxygen demand, chloride sulfate, volatile chlorinated organics, PCBs, dioxins, and furans.

Contamination of soil and groundwater caused by releases from the landfill have been detected over 0.5 km from the landfill. Beginning in June 1984, leachate treatment was performed. Three leachate collection wells were installed during this period to control leachate. From 1984 to 1985, landfill covering and revegetation were performed. In December 1990, a remediation plan was accepted, with a cutoff wall planned for 1991. The current status of the remediation work is not known.

Reported remediation costs are as follows:

- 1st and 2nd investigation phases of approximately DM 10-million;
- leachate pretreatment of approximately DM 10-million;
- cover construction 1st phase of approximately DM 5-Million; and
- encapsulation, cut-off wall and drainage measures of approximately DM 40-60-million.

Sources: (Hösel, et al., undated)

A-10 Marktredwitz (Bavaria)

The site of the former Chemische Fabrik Marktredwitz is in a residential area of the town of Marktredwitz, located about 80 km northeast of Nürnberg in eastern Bavaria. It is described as being Germany's oldest chemical manufacturing site, having operated for almost 200 years until the facility was closed in 1985. The site has been the center of a national pollution scandal. For years the factory was operated in violation of safety standards without notice by regulators. The managers of the family company, Rolf and Oskar Tropitzch, went on trial with a resulting DM 190,000 fine. Most charges against them were dismissed by the court, and the company has subsequently been declared bankrupt. The site area was about 1.5 ha, but with adjacent properties, the contaminated ground area is approximately 2 ha.

At the site, compounds of mercury, antimony, arsenic, and cyanide were manufactured. Up until 1939, waste water was discharged untreated into the adjacent Kösseine River. Prior to closure, the site had leakages from the waste water system, unlicensed discharges of toxic materials into the ground and the surface waters, illegal disposal of production residues, local area contamination from air pollution, and inadequate materials handling and production control procedures. Contamination of the site itself occurred to a depth of about 3 m, with an average mercury content of the soil and the demolition materials of about 1,000 mg/kg. Other contaminants besides the manufactured materials included lead, cadmium, and organic solvents. It has also been reported that contamination of the river and associated floodplain has occurred, but details regarding this are not available.

Following closure, the production equipment was dismantled and about 3,000 tonnes of hazardous materials were transported in sealed steel canisters for placement in the underground special waste repository located at Herfa-Neurode. A wall of intersecting bored piles 20-m deep was constructed to protect the river. Current operations include demolition of the buildings, after which the contaminated soil is to be cleaned to a target concentration of 50 mg/kg of mercury using a thermal (400 C–) and vacuum distillation process on the finer fraction. This is intended to recover 90% of the mercury. A special landfill has been constructed for the materials produced during the remediation process, including the treated soil.

It is estimated that the total remediation cost will be more than DM 100 million. Most of this (90%) is covered by the State of Bavaria.

Sources: (Franzius et al., 1992) (Thome-Kozmiensky, 1988) (Kompa et al., 1989)

A-11 Schönburg Landfill (Mecklenburg-Western Pomerania)

The Schönburg landfill, located adjacent to the village of Selmsdorf approximately 15 km east of Lübeck, is the largest landfill on the European continent. The landfill was part of East Germany's strategy to get hard currency from the West. For more than a decade, Western European municipalities and industries disposed of more than 10 million tonnes of waste at the site, generally without any concern for the nature of the waste.

The landfill has been sold to the State of Mechlenberg - western Pomerania, by the Treuhandanstalt for DM 10-million and is operating under improved safety standards and design. Approximately 40,000 tonnes of waste are disposed of daily, with a total of 1.2-million tonnes of waste landfilled at the site in 1991. However, beginning in 1995, western German states will not be allowed to landfill wastes at the Schönburg landfill, to reserve capacity for the eastern German states, where landfill capacity is very limited. The future owner is expected to be the state-owned waste and contaminated sites management firm, Gesellschaft für Abfallwirtschaft und Altlasten Mecklenburg-

Vorpommen mbH, which will likely lease the landfill to private operators. A detailed site investigation has not been performed. However, it is expected that a DM 30 million reserve will be passed on to the new operators for remediation of old sections of the landfill and for site investigations.

Source: (Haznews, 1992b) (Haznews, 1992c)

A-12 Deponie Antonie (Saxony-Anhalt)

Deponie Antonie is a former open pit lignite mine that was used for chemical waste disposal by Chemie AG. It is located directly west of the Bitterfeld Central Chemical Works of Chemie AG, in Bitterfeld (Saxony-Anhalt). Lignite excavation at the site was completed in 1914. From the 1920s to 1945, the pit was used for the disposal of lignite ash and inorganic waste. After 1945, Chemie AG used the pit for waste disposal. Between 1962 and 1982, approximately 20,000 m^3 of isomers of hexachlorocyclohexane were deposited in the open pit. Other wastes disposed of include neutralization sludges, benzylchloride residues, sulfuric acid with toluene, tar residues, and distillation residues (including tetrachloroethane, trichloroethylene, perchloroethylene, and hexachloroethane). The area of the former pit is 31 ha. The pit is unlined and some of the waste materials are in a saturated zone that is well connected with the sandy aquifer surrounding the facility.

Detailed investigations are planned for this site, but have apparently not yet been performed. Based on regional observations, groundwater in this area is heavily contaminated. Downgradient concentrations detected in the shallow aquifer include 16,700 mg/l of chemical oxygen demand; 8.9 mg/l zinc; 17.5 mg/l of adsorbable organic halides; 1,560 mg/l of chloride; and 0.95 mg/l of phenol. In underlying Tertiary strata, 46 µg/l of monochlorophenol and 228 mg/l adsorbable organic halides were detected. However, Deponie Antonie is not the only potential source area for groundwater contamination in this area, and the effect of other sites will need to be considered as part of the site investigation.

Remediation is still in the planning and investigation stages. Because of high cost, a containment option rather than a full cleanup attempt is probable.

Source: (Krapp et al., 1992)

A-13 Heideloh (Saxony-Anhalt)

Heideloh is a hazardous waste disposal site located about 7 km west of Bitterfeld in Saxony-Anhalt. The site was initially used for the excavation of sand and gravel. Between 1965 and 1970 the site was filled with demolition debris from a polyvinyl chloride (PVC) processing plant and with materials from DDT and hexachlorocyclo-hexane facilities belonging to the Elektrochemischen Kombinats Bitterfeld. After filling, the site was used for agricultural purposes. Ownership prior to 1982 is unclear. In 1982, the site was taken over by Braunkohlenkombinat Bitterfeld as part of a potential lignite open-pit development. Groundwater extraction wells were installed in connection with the mine development. During mine development excavation work in 1987, the disposal site was accidentally discovered. Upon discovery, the excavation workers were affected by strong headaches as a result of vapor exposure. The site is about 5,500 m^2 in area with an estimated fill thickness ranging from 0.4 m to 6.8 m and a volume of 20,000 m^3 of contaminated soil.

Investigations were performed in late 1987 or 1988 shortly after discovery of the site. Fifteen boreholes were drilled to determine the extent of the waste. Samples obtained during the borehole investigation contained DDT, hexachlorocyclohexane, and chlorinated volatile organics. Water sampling was performed to assess contamination pathways. Total hydrocarbon concentrations in groundwater samples from adjacent open-pit dewatering wells varied from 0.02 mg/l to 0.68 mg/l. Groundwater contamination has affected the potential public use of water obtained from the peripheral open-pit dewatering wells.

From April to June 1988, remediation was performed at the site. The contaminated areas were covered with a 0.3- to 0.5-m-thick layer of non-cohesive soil, followed by a 1.4-mm-thick CPE membrane, and then overlain with more compacted noncohesive soil. A final cover consisting of 4 to 6 m of spoil from the development of the adjacent open pit was then placed on top.

Costs for remediation were reported in East German Marks. Assuming an exchange rate of 1.8 East German Marks per Deutsche Mark, costs were:

- preparatory works at DM 8,930;
- earthworks (planning) at DM 620;
- earthworks at DM 200, 200 ; and
- membrane at DM 146, 220.

Source: (Hösel et al., undated)

A-14 Wismut AG (Thuringia and Saxony)

Wismut AG (Wismut) is a group of uranium mining and processing sites located in eastern Germany, primarily in Thuringia and Saxony. Mining has been performed in the Erzgebirge (ore mountains) for centuries. Uranium mining on a large scale was begun by the Soviets following World War II. Prior to reunification, the operating company was called SDAG Wismut, a joint Soviet-East German organization. The current company is owned by the federal government of Germany, and as of 1990 most production-related mining operations were discontinued.

About 400 industrial sites connected with mining and processing were operated at various times by Wismut. Some of the major sites include:

- Königstein, an underground acid leaching operation located approximately 25 km southeast from the center of Dresden along the Elbe River;

- Aue region, an area of deep underground mining near the town of Aue about 30 km southwest of Chemnitz;

- Ronneburg area, an open pit and underground mining area located approximately 9 km east of Gera, with a total of 1,760 ha and a total estimated waste quantity of about 130 million m^3; and

- Seelingstädt, a mineral processing facility located approximately 15 km southeast of Gera, with 4.4-million tonnes annual capacity, and associated tailings containing about 100-million tonnes of tailings covering approximately 200 ha.

Uranium mining and processing operations have resulted in the release of radioactive and chemically active materials. These include releases of radon from waste piles and mine ventilation, dust from tailings ponds, and contaminated drainage water from mine sites. Continued oxidation of pyrite in waste materials and in the mines is expected to increase acid groundwater conditions and associated metal leaching problems.

Prior to 1990, limited monitoring programs (including radon monitoring) were in place. Investigations connected with decommissioning were started in 1990, following the effective closure of the mining complexes. Gamma surveys were made in the areas in and around the operational areas, followed by sampling and chemical analysis of soil, groundwater, and surface water. Additional investigations were performed to improve the hydrogeologic characterization of some of the individual sites, and test programs of potential decommissioning components, such as water treatment plants, were instituted.

Under current conditions, the principal environmental and health risks result from the discharge of mine drainage water and air circulation through mine workings. Physical hazards may also arise because of the close proximity of housing to many of the sites. Flooding of the underground mines has significant effects on surface and groundwater flows and qualities.

Although remediation planning has begun, very limited field work has been carried out pending government approval. Costs for decommissioning have been estimated to range from DM 5 to 20 billion.

Source: (Nuclear Assurance Corporation, 1990)

A-15 Firma Oel Pintsch Gmbh. (Berlin)

Firma Oel Pintsch Gmbh. was a waste oil processing facility located in the Britz area of Berlin, in former West Berlin. The facility was operated from the mid-1920s, until it was destroyed by fire in 1981. It covers approximately 16,000 m^2. Waste materials, including sludges, acid tars, and solvents, were discharged into open pits. Leaks and spills of mineral oil, PCBs, polyaromatic hydrocarbons, and phenols resulted from leaky pipes and wartime damage.

After the fire, investigations were performed. Seventeen boreholes were drilled at the site and 23 water level probes were driven. Groundwater and soil samples were obtained and analyzed. Water samples from near the water table had the following concentrations: 1 to 161,700 mg/l of aliphatic hydrocarbons, 19 to 1,043 mg/l of coal tar oil (aromatics), and 0.09 to 226 mg/l of chlorinated hydrocarbons. Soil and groundwater contamination were reported on adjacent sites. Groundwater depth at the site is approximately 8.5 m.

In October 1984, remediation was initiated by removing the site buildings and installing eight groundwater recovery wells. In each of these, "rope-mop-wringer" equipment was installed to remove floating product. This system consisted of a rope loop with mop sections attached. The loop was installed in the well so that the lower end was in the floating product zone. Continuous rotation of the loop brought product to the surface in the mop sections. The rope passed through a wringer at the surface to recover the product. The state government of Berlin is paying for site remediation.

Source: (Franzius et al., 1992)

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APPENDIX B

RECENT CASE STUDIES IN GERMANY

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RECENT CASE STUDIES IN GERMANY

Table B-1: Recent Case Studies in Germany

The table contains 21 case studies of recent environmental restoration projects in Germany. The projects provide a representative cross section of the types of remediation programs performed in Germany. The technologies used are fairly standard, but some innovative applications were performed. Each project is described in terms of:

- project name and location;
- type(s) of contaminants (if known);
- remediation technologies employed; and
- reference.

Table B-2: BMFT Funded Projects (1984-1990)

Table B-2 contains a list of all of the waste management and environmental projects funded by the BMFT during the period 1984 to 1990. The projects are grouped by the general categories such as the type of treatment (e.g., in situ remediation, safeguarding), process involved (e.g., thermal, biological), etc. Additional information can be found in BMFT (1991b).

Table B-3: Areas of Future BMFT-Sponsored Research and Development in Environmental Restoration

Table B-3 contains a list of the specific areas in environmental restoration in which the BMFT plans to support research and development in the next several years. The list was compiled from BMFT publications, primarily BMFT (1989).

Table B-4: Useful Addresses and Phone Numbers

This table contains an extensive of list of agencies, institutes, publications etc. associated with environmental matters or research in Germany.

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TABLE B-1. RECENT CASE STUDIES IN GERMANY

Project/Contaminant	Remediation	Reference
Chemical pharmaceutical plant - Hamburg/ PCDDs and PCDFs	Excavation, thermal treatment and replacement of contaminated soil. Pumping of contaminated groundwater (chlorobenzene).	Jurgens,H. and R.Roth, "Case Study and Proposed Decontamination Steps of the Soil and Groundwater Beneath a Closed Herbicide Plant in Germany," Chemosphere CMSHAF, v.18, n.1-6, p. 1163-1169, 1989.
CH Boehringer chemicals Hamburg Moorfleet pesticide plant/dioxin TCDD	Incineration of contaminated soil/building rubble and groundwater "overhaul".	Frankfurter Allgemeine Zeitung, p. 22, Sept. 22, 1990.
Munchehagen - Hannover	Subsurface sealing (by longwall mining techniques).	Chadwick, J., "Longwall to Save Landfill Time-Bomb?," Mining Magazine, p. 340-341, June 1992.
Dresden landfills remedial work/mixture of uncontrolled hazardous wastes	(79.5mDM) planned.	Haznews, n. 31, p. 11, October 1990.
Stuttgart filling station/PCB, polyaromatic hydrocarbons, mineral oil	Oecotec high pressure soil washing in mobile plant (by Kloeckner).	"Clean Dirt," World Water and Environmental Engineer, p. 15, November 1991.
Buna - Schkopau/cyanide and mercury	by Umwelt-Ingenieur-GmbH.	"Cleanup Companies for Sachsen-Anhalt," Haznews, n. 40, July 1991.
Cleanup of abandoned Chemische Werke Buna AG chemical site in East Germany/mercury	Excavation, screening/crushing, incineration in rotary kiln, and multiple gas cleaning stages (by LUB).	Haznews, n. 41, p. 8, Aug. 1991.
Soil and groundwater cleanup at clock factory in Senden/chlorinated hydrocarbons, cyanide and heavy metals	Planned.	Haznews, n. 35, p. 6, Feb. 1991.
Soil cleanup at Robert Müser mine in Bochum/tar oils, benzene, toluene, xylene and polycyclic aromatic hydrocarbons	Deconterra 2-step wet mechanical separation process (by LUB for Harpener AG).	Haznews, n. 38, p. 8, May 1991.
Vereinigte Deutsche Metallwerke (VDM) AG site in Frankfurt-Heddernheim/organic and inorganic pollutants, e.g., volatile chlorinated hydrocarbons, polycyclic aromatics and heavy metals.	Excavation, Deconterra 2-step wet mechanical separation process (by LUB), and landfill or incineration of residue.	Haznews, n. 43, p. 4, Oct. 1991; LUB brochure.
Stadtallendorf munitions site in Hesse/chemicals and explosives including TNT	Excavation, Deconterra 2-step wet mechanical separation process (by LUB), and incineration of residue.	Haznews, n.43, p. 4, Oct. 1991; LUB brochure.
Cleanup of soil and demolition material ($7,000m^3$) of cable reprocessing plant at Maulach, Baden-Württemberg/dioxins and furans	Removal and landfilling in specially designed monofill site (8.5mDM).	Haznews, n. 41, p. 8, Aug. 1991.

TABLE B-1. (Cont.) RECENT CASE STUDIES IN GERMANY

Project/Contaminant	Remediation	Reference
Cleanup of Pintsch used oil plant/oil, solvents and special wastes	(188.5mDM since 1984)	Haznews, n. 48,p. 10, March 1992.
Treatment of dredged material from Hamburg harbor/organic and inorganic toxic compounds	Mechanical treatment of harbor mud (METHA) plant (2mt/yr, 100mDM construction cost), whereby fines are separated from coarser particles, the coarse materials are washed and used as building materials, the fines are floculated and then dewatered, and then stored for ultimate use as ceramic burnt pellets for construction material (by LUB).	LUB brochure.
Georgswerder	Pilot study regarding detection/recycling of gas, seepage/leachate treatment (especially dioxin contaminated), surface sealing, seepage minimization, and information/analysis/modeling of spatial distribution of contamination.	BMFT, 1991b.
Gerolsheim/Hazardous Waste.	Encapsulation of landfill; pilot study regarding sealing wall system, surface sealing system, emission/transport behavior of gas, gas/seepage treatment, and long term behavior	BMFT, 1991b; UFORDAT, 1992 (BMFT research: Handzik, K.H., Dipl.-Ing., c/o Gesellschaft zur Beseitigung von Sonderabfaellen Rheinland-Pfalz, Postfach 2180, D-6500 Mainz, RP, Tel.: 49-6131-23930).
Bönen GFR	In-situ biological treatment by Ruhrkohle AG.	Ebel, 1988.
Mansfelder Land - Sachsen-Anhalt	N/A	"Financial Aid for Germany's Bitterfeld Region," Haznews, n. 39, June 1991.
Gas plant Solingen/polycyclic aromatic hydrocarbons	Microbiological remediation from 120 mg/kg to 10 mg/kg.	UFORDAT, 1992 (BMFT research: Steilen, N, Dipl.-Ing., c/o GERTEC, Viehofer Str. 11, D-4300 Essen, NW, Tel.: 49-201-245640).
Cox Plant Herne/benzol, toluol, xylol, polycyclical aromatic hydrocarbons	Combination of two drainage systems (for groundwater and soil air) and a well system for air injection.	UFORDAT, 1992 (BMFT research: Kueper, J., Dipl.-Geol., c/o Stadt Herne, Amt fuer Umweltschutz, Postfach 1820, D-4690 Herne, NW Tel.: 49-2323-162540 Telex: 8229872 skhr d).
Note: This is a representative (rather than a comprehensive) list.		

TABLE B-2 BMFT SPONSORED PROJECTS IN ENVIRONMENTAL RESTORATION (1984-1990)

RESIDUES FROM FLUE GAS AND EFFLUENT TREATMENT PROCESSES	
Bundesverband Flugstaub e.V.	Comparative investigations of carbonation of concretes.
Steag AG/Bischoff GmbH & Co KG	Construction and operation of a pilot plant for the manufacture of high-quality plaster for use underground.
VGB-Forschungs-stiftung	Dependence of fly ash quality on the design of furnace quality and coal used.
Steinmüller GmbH	Utilization of products from fluidized bed furnaces for steam boilers.
FHG Frauenhofer GmbH	Suitability of binders from flue gas desulphurization plants for manufacturing gypsum-bound chipboard.
BGR-Bundesanstalt für Geowissensch. und Rohstoffe	Residues from air purity facilities and sewage treatment plants. Examination of fine dusts.
Klöckner Stahl GmbH	Development of a commercial process for the economic recycling of filter dusts.
Peine Engineering GmbH	Feasibility study on the use of gypsum from desulphurization plants for new kinds of gypsum products.
GFR - Ges. zur Auf-bereitung & Verwertung von Reststoffen GmbH	Processing of residues from power plants to reduce environmental pollution.
Wärmetechnik und Industrieautomati-sierung GmbH	Process to render inert residues from flue gas scrubbers by vitrification.
COLLECTION, TRANSPORT, SEPARATION OF WASTES AT SOURCE FOR TREATMENT	
Hessische Industrie-müll GmbH	Demonstration project for testing a system for collecting small quantities of hazardous waste.
Dornier-System GmbH	Definition of the project multi-compartment waste system.
Landkreis Bad Dürkheim	Comparative investigations: recovery of usable materials from waste.
FH Münster	Disposal in rural areas using different operations systems.
GHS Kassel	Analysis of the structure of East Germany's SERO system with regard to efficiency & suitability.
IMPROVEMENT OF THERMAL WASTE TREATMENT PROCESS (INCLUDING FLUE GAS SCRUBBING AND RECYCLING OF RESIDUES)	
Hess. Industrie-müll GmbH (HIM)	Planning, building and monitoring of a thermal treatment plant for hazardous waste.
LK Göppingen	Installation of a waste/sewage sludge homogenizing plant.
Zweckverband Ostholstein	Examination of a flue gas scrubbing system based on wet dust extraction and wet adsorption.
Baubehörde der Freien und Hansestadt Hamburg	Investigation into the causes and possible ways of reducing PCFF/PCDF emissions.
Hugo Petersen GmbH & Co. KG	Joint project: Precipitation of toxic compounds from flue gases in waste incinerator plants.
BSR-Berliner Stadtreinigungs-Betriebe	Practical concepts for reducing the formation of polychlorinated dibenzodioxins.
MVA Stapelfeld GmbH	Causes and reduction of PCDD/PCDF emissions from three waste incineration plants in Schleswig-Holstein.
Krupp GmbH	Processing filter ashes from waste incinerating plants to make concrete aggregates.
Landesanstalt für Immissionsschutz NRW	Dioxin emissions from waste incineration plants.
Deutsche Babcock Anlagen AG	Joint research project: Incineration experiments to minimize PCDD/PCDF formation -Part 1-.
Uni Hamburg	Joint project: Precipitation of PCDDs, PCDFs, PAHs, PCBs, and other elements & compounds -Part 2-.

TABLE B-2 (CONT) BMFT SPONSORED PROJECTS IN ENVIRONMENTAL RESTORATION (1984-1990)

Uni Bayreuth	Joint project: Incineration experiments to minimize the formation of PCDD/PCDF -Part 2-.
Deutsche Babcock Anlagen AG	Treatment of filter dusts with acidic scrubbing water in order to leach out heavy metals.
Landratsamt Göppingen	Joint project: Study of PCDD/PCDF emissions from the waste-fuelled heating/power station at Göppingen.
Rhein-Neckar AG	Joint project: Study of PCDD and PCDF emissions at the waste incineration plant at Mannheim.
Gewerbeaufsichts-amt des Saarlandes	Joint project: Examination of PCDD and PCDF emissions at a waste incineration plant.
TU Berlin	Coordination, recording and evaluation of measurements of dioxins at waste incineration plants.
TU Berlin	All-round study of the residue problem at waste incineration plants/wet process.
Krupp MAK Maschinenbau GmbH	Thermal reconditioning of air-borne dust and dust from filters in waste incineration plants using plasma furnace technology.
Uni Essen	Basic investigation into the emission of bromide compounds, using the example of waste incineration.
Martin GmbH	Joint research project: Reduction of emissions from waste incineration plants, Part 3. Improvement of the combustion behavior.
Müllverbrennungsanlage Stapelfeld GmbH	Joint research project: Use of industrial by-products and recycled materials in road construction -Part 2-.
Universität Hamburg	Joint research project: Use of industrial byproducts and recycled materials in road construction -Part 3-.
K+K Ofenbau GmbH	Joint project: Reduction of emissions...Optimization of combustion of waste incineration plants.
Steinmüller L. & C. GmbH	Joint project: Reduction of emissions...Optimization of combustion at waste incineration plants.
APPLICATION POSSIBILITIES FOR OTHER THERMAL WASTE TREATMENT PROCESSES	
LK Günzburg	Waste pyrolysis plant at Günzburg.
Landratsamt Ostalbkreis	Demonstration unit Kiener system (II).
Sonnenberg Thermotechnik GmbH	Process pyrolysis...for the recovery of usable material from the composite material.
TU Berlin	Use of WDF (waste-derived fuel) for producing energy in power stations - Phases I and II.
Salzgitter Pyrolysis GmbH	Construction and testing of a commercial low temperature pyrolysis plant for disposal.
Trienekens GmbH	Manufacture of high-quality fuel from (pre-sorted) waste.
NUKEM GmbH	Development of a process for the destruction of higher chlorinated hydrocarbons.
NUKEM GmbH	Chemical decomposition of higher halogenated hydrocarbons in a laboratory-simulated plant -Phase II-.
Thyssen Engineering GmbH	Testing of fluidized bed firing as an effective combustion system.
BSR - Berliner Stadtreinigungs-Betriebe	Construction of a demonstration plant for fluidized bed combustion for environmentally sound thermal treatment of waste.
VAW - Vereinigte Aluminium-Werke AG	Joint project: Development of technology for reutilization and disposal of residues from industrial processes.
Deutsche Babcock Anlagen AG	Development of a filter to eliminate dust from hot untreated pyrolysis gases.

TABLE B-2 (CONT) BMFT SPONSORED PROJECTS IN ENVIRONMENTAL RESTORATION (1984-1990)

Brühne Baustoff - und Transport GmbH & Co. KG	Environmentally sound thermal process for reutilizing waste: Generation of a lean gas.
Lurgi GmbH	Development of an integrated waste disposal concept on the basis of gasification in a circulating fluidized bed furnace.
BC - Berlin Consult GmbH	Pyrocom Process: Disposal of electrical and electronic wastes.
Chemieanlagenbau Leipzig-Grimma	Plasma pyrolysis process for the effective production of basic chemicals.
CHEMICAL, PHYSICAL, MECHANICAL WASTE TREATMENT	
Trienekens GmbH	Optimization of process technology and products in commercial waste processing plants.
Westd. Baustoff-Recycling GmbH	Treatment of brick and concrete rubble by grinding and classification.
Schönmackers Umweltdienste GmbH	Development, construction, optimization and experimental operation of a sorting plant for the separation of wastes.
Nukem GmbH	Conditioning of water-soluble hazardous waste so that it can be safely deposited in landfills.
TU Hamburg-Hamburg	Mechanical processing of contaminated harbor silt.
Freie and Hansestadt Hamburg	Mechanical processing of contaminated harbor silt in order to reduce the area needed for depositing it.
Maschinenfabrik Bezner GmbH & Co. KG	Development, construction and optimization of a prototype for a sorting plant.
TU Hamburg-Harburg	Treatment of excavated material to immobilize pollutants.
AGR-Abfallbeseitigungsgesellschaft Ruhrgebiet mbH	Balancing and optimization of the plant and waste management aspects of the waste sorting plant.
BIOLOGICAL WASTE TREATMENT	
LK Aurich	Demonstration plant.
TU Berlin	Carrying out and evaluating experiments on the controlled anaerobic treatment of waste.
Region Schwarzwald-Baar-Kreis	Pilot project: Process for turning organic waste components into biogas.
Riedwerke Kreis Groß-Gerau	Construction and optimization of an automatic measuring, control and documentation system.
BTA Biotechnische Abfallverwertung GmbH & Co. KG	Cooperative project: utilizing biological waste - wet waste, Part I: pilot plant for anaerobic fermentation.
Landtechnik Günter Grube GmbH	Cooperative project: Utilization of biological waste - wet waste, Part II: Pilot project on composting.
Uni Stuttgart	Joint research project "New composting methods" Parts 1, 2, and 5: Emissions from composted waste (heavy metals).
TU Hamburg-Harburg	Joint project: "New composting methods", Parts 4, 6, and 10: Emissions caused by composting biogenous waste.
Fachhochschule Münster	Joint research project "New composting methods", Part 7: criteria for evaluating quality.
UTEC GmbH	Joint research project "New composting methods", Part 8: optimization of the process technology for composting rumens.
LANDFILL SITES	
Universität Kiel	Seismic prospecting; process to detect build up of ground water at landfills.

TABLE B-2 (CONT) BMFT SPONSORED PROJECTS IN ENVIRONMENTAL RESTORATION (1984-1990)

BGR - Bundesanstalt für Geowissenschaften und Rohstoffe	Joint project: Methods to identify and describe the subsoil of landfills and abandoned sites/I and II.
LANDFILL SEALING SYSTEMS	
TU Braunschweig	Development of testing procedures and rules for manufacturing seals for landfills from clay.
Uni Bochum	Examination of the migration of organic pollutants through mineral seals.
Batelle-Institut e.V.	Comparative investigations and evaluation of monitoring systems for landfills.
Ed. Züblin AG	Development of a process for the manufacture of additional underground seals for the base of landfills.
Dr.-Ing. W. Issel	Monitoring system to detect and locate leaks in landfills.
TU Braunschweig	Investigation into the effectiveness of drainage layers in base seal systems in landfills.
Fördergeme inschaft Süddeutsches Kunststoff-Zentrum e.V.	Assessment of long-term behavior of joints in plastic seals in landfills.
BAM - Bundesanstalt für Materialforschung und -prüfung	Joint research project: "Landfill sealing systems" (Currently total of 10 projects and Project coordination).
THE BODY OF THE LANDFILL	
TU Braunschweig	De-gasing in the landfill at Braunschweig.
Abwasserverband Braunschweig	De-gasing in the landfill at Braunschweig and the utilization of the gas in unit power stations.
TU Braunschweig	Stabilization of landfills by re-circulating the leachate.
Uni Hannover	Stabilization of landfills by re-circulating the leachate.
Landkreis Schwäbisch-Hall	Optimization of the processes used at the Schwäbisch-Hall decomposition landfill - Phase II.
Uni Bochum	Investigation on subsurface compacting of landfills.
Dr. Dr. Anton Maier AG	Development and construction of a semi-commercial prototype for the treatment of waste water from a landfill for hazardous waste.
Uni Dortmund	Processing of landfill gas and gas from sewage works using a molecular process to achieve a higher valence.
TU Hamburg-Harburg	Investigations on a laboratory scale into the acceleration of the anaerobic biochemical transformation processes in landfills.
Uni Stuttgart	Development of concepts for safety measures in the planning of gas suction and gas utilization plants.
Forschungsgemeinschaft Kalk und Mörtel e.V.	Development of a process using lime products to facilitate the depositing of contaminated sludge.
ESWE-Institut für Wasserforschung und Wassertechnologie e.V.	Investigation of the release of harmful substances when sludges from the purification of drinking water are deposited.
Interatom GmbH	Acceleration of gas production from landfills by optimizing the operation.
SBW - Gesellschaft zur Beseitigung von Sonderabfällen mbH	Development of comprehensive concepts for the treatment of leachate contaminated by dioxins.
Bergbau-Forschung GmbH	Removal by adsorption of chlorinated hydrocarbons from landfill gases; Use of the gases.

TABLE B-2 (CONT) BMFT SPONSORED PROJECTS IN ENVIRONMENTAL RESTORATION (1984-1990)

MAN Technologie AG	Joint project: Utilization of landfill gas. Part 2: Development of a process to remove pollutants from landfill gases.
TH Aachen	Cooperative project: Utilization of gas from landfills. Part 3: Plant for concentrating landfill gas.
TU Braunschweig	Determination of soil parameters relevant to construction.
TU Berlin	Investigation into formation of harmful substances during the combustion of landfill gases and possibilities of reducing them.
TU München	Evaporation plant for treating leachate occurring in landfills.
Depogas GmbH	Investigations into engineering technology to reduce halogenated hydrocarbon compounds in gas.
BMZ - Bundesminister für Wirtschaftliche Zusammenarbeit	Pilot project at the King-Tom landfill in Sierra Leone to demonstrate utilization of gas from landfills in humid tropical countries.
LANDFILL OBSERVATION, AFTER-CARE	
Landesanstalt für Umweltschutz Baden-Württemberg	Demonstration of long-term examinations on selected landfills - Scientific coordination.
RECORDING AND RISK ASSESSMENT FOR CONTAMINATED SITES	
Bundesgesundheitsamt Berlin (BGA)	Effects of abandoned waste sites on the ground-water in Berlin as a case study.
Battelle-Institut e.V.	Sounding of contaminated sites (Phase II). Design and construction of an improved system.
Battelle-Institut e.V.	Sounding of contaminated sites (Phase III): Optimization of the radar probe.
LK Nienburg/Weser	Examination of redevelopment potential for contaminated sites using the abandoned landfill at Münchehagen as an example.
Uni Hannover	Analysis of and prognosis for spread of harmful substances into the groundwater in the vicinity of abandoned landfills.
Bundesgesundheitsamt Berlin (BGA)	Development of methods and yardsticks for the standardized assessment of abandoned landfills and contaminated industrial sites.
Merk-Holzbau GmbH & Co.	Decontamination of soil and groundwater which has been contaminated by wood preservatives.
Bundesforschungs anstalt für Forst und Holzwirtschaft	Decontamination of soil and groundwater which has been contaminated by wood preservatives.
TFH Berlin	Development of an information system for recording and evaluating abandoned sites in the region of Halle/Bitterfeld.
Bergakademie Freiberg	Complex geophysical identification of abandoned sites with regard to structure and physico-chemical characterization.
SAFEGUARDING MEASURES FOR CONTAMINATED SITES	
DYNAMIT NOBEL AG	Injected gels for decontamination of abandoned sites.
Stadt Frankfurt a.M.	Demonstration of additional groundwater protection in a large-scale landfill.
Freie und Hansestadt Hamburg	Joint project: New processes and methods for decontaminating abandoned sites using the example of the Georgswerder landfill.
Ed. Züblin AG	Development of processes for the construction of multi-layered sealing wall systems.

TABLE B-2 (CONT) BMFT SPONSORED PROJECTS IN ENVIRONMENTAL RESTORATION (1984-1990)

Institut für Bauphysik und Bauchemie	Behavior under physical and chemical strain of tempered cement pastes.
GBS - Gesellschaft zur Beseitigung von Soderabfällen	Gerolsheim joint project: Part 1: Selection and optimization of suitable systems of sealing walls to contain leachate and gas.
GBS - Gesellschaft zur Beseitigung von Sonderabfällen	Gerolsheim joint project: Part 2: Selection and optimization of suitable systems of surface seals which are impermeable to rain-water.
GBS - Gesellschaft zur Beseitigung von Sonderabfällen	Gerolsheim joint project: Part 3: Measurement, balancing, evaluation and reduction of emissions and migrations of gas.
GBS - Gesellschaft zur Beseitigung von Sonderabfällen	Gerolsheim joint project: Part 4: Development of techniques for removing sulphur and chlorine compounds from landfill gas and flue gas.
GBS - Gesellschaft zur Beseitigung von Sonderabfällen	Gerolsheim joint project: Part 6: Assessment of the long-term behavior of the landfill.
GBS - Gesellschaft zur Beseitigung von Sonderabfällen	Gerolsheim joint project: Part 7: Administrative and scientific coordination of the project.
GBS - Gesellschaft zur Beseitigung von Sonderabfällen	Joint project: New techniques and methods for decontaminating abandoned sites using the Gerolsheim landfill as an example.
ON-SITE/OFF-SITE DECONTAMINATION	
Harbauer GmbH & Co. KG	Development of a re-processing plant for contaminated soil - laboratory phase.
Harbauer GmbH & Co. KG	Joint research project: chemical-physical processes for decontamination of abandoned sites. Part 1: Development of a reprocessing plant.
Ed. Züblin AG	Thermal cleansing of soils contaminated predominantly by organic substances.
Ruhrkohle AG	Construction and trial of a transportable cylindrical rotating furnace for the thermal treatment of wastes.
Uni Göttingen	Decontamination of soil polluted with organic substances by composting with straw.
Ruhrkohle Öl und Gas GmbH	Development of microbiological/adsorption methods for on-site decontamination of soil.
Bremer Vulkan AG	Joint project: Development of a technical process for removing environmental pollutants from soil Part 2.
RWTH Aachen	Decontamination of an abandoned site: On-site treatment and utilization of organically contaminated soil.
Ziegelwerk Anton Grehl	Development of a pollutant-free ceramic process to treat materials in soil which contain energy.
RP Darmstadt	Laboratory and field tests on microbiological decontamination of refinery sites which have been contaminated by used oil.
Forschungsinstitut für Aufbereitung	Redevelopment of abandoned sites for waste management purposes.
IN-SITU DECONTAMINATION	
Institut für Umweltanalytik und Biotechnologie GmbH	Use of specific micro-organisms for the decontamination of abandoned sites. An in-situ or on-site process.
DMT-Gesellschaft für Forschung und Prüfung	Joint project "Biochemical decontamination of abandoned sites" Part 1: Development of micro biological/adsorption methods.
Degussa AG	Joint project "Biochemical decontamination of abandoned sites"-Examination of the application potential of hydrogen peroxide.

TABLE B-2 (CONT) BMFT SPONSORED PROJECTS IN ENVIRONMENTAL RESTORATION (1984-1990)

Haftpflichtverband der Deutschen Industrie V.a.G.	In-situ decontamination in a case of pollution caused by hydrocarbons at a brewery.
Uni Karlsruhe	In-situ decontamination of soil polluted with hydrocarbons (Karlsruhe Gasworks).
Bauer Spezialtiefbau GmbH	Field test of in-situ decontamination of soil polluted by hydrocarbons.
TU Braunschweig	Development of a process for biological additional treatment (in-situ) of an industrial site contaminated by solvents.
METHODS FOR CHECKING FOR SUCCESS AND MONITORING OF REMEDIATED SITES	
Batelle-Institut e.V.	The planning of a mobile laboratory for the examination of abandoned waste disposal sites.
Uni Hamburg	Pedological investigations into thermal, chemical and biological techniques for cleansing soil.
Stadt Dortmund	Joint R&D project Dortmund: Further development and testing of decontamination technology, Parts 1 and 2.
PROBIOTEC GmbH	Procedural aspects and general conditions in decontamination of abandoned sites in the Federal Republic of Germany.
PLANNING, PROGNOSIS, ANALYSIS FOR CONTAMINATED SITES	
IWL - Institut für gewerbliche Wasserwirtschaft und Luftreinhaltung e.V.	Examination of the stage of development of methods for on-site decontamination of abandoned sites.
Probiotec GmbH	Examination and evaluation of bioengineering techniques for in-situ decontamination of soil and sub-soil.
FIW-Forschungs institut für Wasser technologie	Joint project: Recording and assessment of decontamination measures for abandoned sites Part 1: Status report on research.
GAB GmbH	Representative study of the contents of oil precipitators and emulsions in Berlin and West Germany.
PROJECTS MANAGED BY KFK	
Landkreis Gifhorn	Decontamination of an unauthorized hazardous waste tip (abandoned site) in the rural district of Gifhorn using in-situ processes, process optimization.
TU Braunschweig	Development of a process for in-situ decontamination of abandoned sites using bacteria suitable for the site using the example of a closed-down industrial site.
Biodetox GmbH	Tests on a laboratory and semi-commercial scale to produce reversible inactivated micro-organisms for biodegradation of organic pollutants in soil and groundwater.
Harbauer GmbH & Co. KG	Biological regeneration of carrier material for the adsorption of halogenated hydrocarbons in plants used to decontaminate groundwater.
Niedersächsische Gesellschaft zur Endablagerung von Sonderabfall mbH	Joint project: "Experimental study on depositing waste in salt caverns", Part 1: survey of waste and project definition phase (study to draw up a concept specific to waste management).
Rudolph Otto Meyer KG	Removal of heavy metals from contaminated sludge and soil, Part 2: semi-commercial test to decontaminate aquatic sediments polluted with heavy metals.

TABLE B-2 (CONT) BMFT SPONSORED PROJECTS IN ENVIRONMENTAL RESTORATION (1984-1990)

Niedersächsische Gesellschaft zur Endablagerung von Sonderabfällen mbH	Joint project: Experimental study on depositing waste in salt caverns", Part 2: studies on process development (waste processing and conditioning, methods of delivering the waste and filling the caverns, cavern technology).
Private Universität Witten/Herdecke GmbH	Use of floating trickling filters for treating slurry in standard silos.
Lurgi GmbH	Semi-commercial experiment to treat slurry by wet oxidation.
Wehrle Werk AG	Development of a process for biological treatment of slurry using bark filters.
Rheinbraun AG	Semi-commercial tests to develop a slurry treatment process using lignite for absorptive pre-treatment.
Firma Wech; Institut für Wasser- und Umweltschutztechnologie	Development of an environmentally-sound process to remove heavy metals from excavated earth including recirculation of the process water.
Rud. Otto Meyer KG	Joint project: "Removal of heavy metals from contaminated sludge and soil"; Part II; Semi-commercial tests to decontamination aquatic sediments polluted by heavy metals.
PROJECTS MANAGED BY DLR	
AWFI, Arbeitswissenschaftliches Forschungsinstitut GmbH, Berlin	Development of a dynamic vibration de-watering system for sludge.
R.B.S., Kirchweyhe; Reinigen-Beschichten-Strahlen Gmbh	Development of a disposal system for treating gaseous, liquid and solid residues, demonstrated on the example of tank wagon.
VGU Engineers-Consultans GmbH & Co Umwelttechnik KG	Influence of the selective catalytic reduction of nitrogen oxides with NH_3 on the utilization potential of fly ash and on the possibility of treating the fly ash.
Universität Hamburg	Pyrolysis of shredder waste and oil-polluted sand to dispose of it after recovering materials in a semi-commercial fluidized bed furnace.
D.R.P. Deutsche Reifen- und Kunststoff Pyrolyse GmbH	Testing the demonstration pyrolysis plant in continuous operation, paying particular attention to critical components and parts of the plant.
Asea Brown Boveri AG	Ebenhausen plastics pyrolysis: R&D work on optimization of process technology, increase of effective operating time and demonstration of NT pyrolysis for disposing of selected wastes.
Universität Hamburg	Environmentally relevant tests on pollutants in pyrolysis oils in comparison to other kinds of oil used for technical purposes.
Universität Hamburg	Optimization and extension of the "Hamburg pyrolysis process" in terms of production ranges and use, usable goods and emissions, including checking the technical prototype plant.
Salzgitter AG	Optimization of environmental aspects and process engineering of a thermal treatment plant for hazardous waste which works on a principle of revolving drum pyrolysis.
Salzgitter Pyrolyse GmbH	Testing and optimization of the Salzgitter pyrolysis plant for thermal decomposition of hazardous waste including recovery of materials and energy.
Salzgitter-Pyrolyse GmbH	Testing and optimization of the Salzgitter pyrolysis plant for environmentally sound utilization of special wastes and a study of the economic potential of the plant.
Union Rheinische Braunkohlen Kraftstoff AG	Reduction of environmental pollution by hydration of waste containing carbon.
RWE Gesellschaft für Forschung und Entwicklung mbH	Reduction of environmental pollution by hydration of waste containing carbon - 2nd phase of the project.
TU München	Analysis of process and environmental aspects of new thermal processes - Phase I: Pyrolysis; Phase II: Fluidized bed incineration.

TABLE B-2 (CONT) BMFT SPONSORED PROJECTS IN ENVIRONMENTAL RESTORATION (1984-1990)

PROJECTS MANAGED BY KFA	
Forschungsinstitut für Wassertechnologie an der RWTH Aachen	Assessment model for evaluating the risk potential of abandoned sites.
Stadtverband Saarbrücken	Methodology of a model for estimating and averting danger from abandoned sites in a region.
Stadt Dortmund	Feasibility study for a decontamination system for the site of a coking plant using the example of the Germania coal mine and coking plant in Dortmund.
TÜV Rheinland	Pilot study to develop a process for thermographic study of abandoned sites.
Deutsches Institut für Urbanistik	Abandoned sites under local authority responsibility - an empirical study of the legal, organizational and financial aspects.

Note: Unless otherwise noted, projects are managed by BMFT (ref. BMFT, 1991b)

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TABLE B-3 AREAS OF FUTURE BMFT-SPONSORED R&D IN ER

CONVERSION, HYDRATION, DISTILLATION	
Pre-treatment	The pre-treatment of waste to separate interfering contaminants and to improve the suitability for use of various types of waste of different origin and consistency.
Process optimization	Optimization of the reaction conditions for various mixtures of waste with the aim of attaining a high yield of reusable materials and a reduction in the quantity of pollutants.
Environmental compatibility and treatment residues	Verification of the environmental compatibility of the process with regard to pollutant emissions and environmentally compatible disposal of the residues from the process.
PYROLYSIS	
Efficiency of pyrolysis processes and preconditions for their application Removal of fine dusts from pyrolysis gases Recycling or landfilling of the solid residues Combined pyrolysis-incineration process	
INCINERATION	
Pre-treatment and waste management	Prior to incineration, the main areas of interest are treatment of the waste (crushing, classification and sorting), the introduction of certain additives, separation and storage of the different types of waste and considerations relating to possible changes in "input". (What form does the residual waste assume after further preventative and recycling measures? What is the composition of the pollutant content in the residual waste? Is the residual waste still combustible on its own?) With regard to the incineration of pollutant waste in particular, concepts and processes of waste management must be developed which enable the path followed by the waste up to the point at which it is introduced into the combustion chamber to be monitored and influenced. Only then will orderly charging and defined tasks be possible, thereby facilitating implementation of the flue-gas purification process.
Processes in the combustion chamber and the boiler area	Further development of the actual incineration process covers improvements in the design of combustion chambers and in the burn-out behavior of the solid and gaseous components as well as mineralization of the residues. This area also includes the development of new incineration systems (such as the fluidized bed incineration process for domestic waste), the development of combined incineration processes (such as a mixture of domestic waste and coal in the fluidized bed), and the development of high-temperature and melting chamber firing processes with the aim of obtaining easily recyclable residues and carrying out subsequent treatment of dusts.
Preliminary measures to reduce dioxin emissions	- Improved burn-out of waste and flue-gas constituents - Improved furnace combustion level control systems, to ensure that the supply of combustion air is regulated in accordance with requirements - Use of improved grate systems - Adaption of suitable grate systems to changes in the composition of waste

TABLE B-3 AREAS OF FUTURE BMFT-SPONSORED R&D IN ER (Cont.)

Secondary measures to reduce dioxin emissions	- Preliminary dedusting as an intermediate stage in the cooling phase (hot-gas dedusting) - Control of the operating temperature of the electrostatic filter to reduce the formation of dioxins - Examination of various flue-gas purification systems with regard to their respective contributions towards the elimination of dioxins - Improved dust separation by flue-gas purification systems - Where applicable, adsorptive separation of PCDD/PCDF by activated carbon or hydrated lime
Recycling of incineration residues	The development of processes for the recycling of ashes, filter dusts and other residues from the incineration of waste.
Decentralized incineration plants	The development of decentralized waste incineration plants and integration of these into the local authorities' energy supply concepts (biogas, landfill gas).
CP TREATMENT	
Starting points for the development and further development of chemico-physical treatment processes are provided by membrane technology, evaporation, electrolytic cyanide destruction, ozonization and various stabilization processes. Reduction of the energy and chemical input Increased selectivity of separating processes Extension of the ranges of application for CPT plants Selective detoxification, degrading and immobilization of waste and pollutants	
LANDFILL SITE TECHNOLOGY	
The landfill site and the spreading of pollutants	Examination and stipulation of the influences of the site on the long-term safety of a waste landfill and a general description of suitable sites for waste landfills; simulation of the spread of pollutants at the site of the waste landfill in terms of seepage water, gases and dusts; verification of this simulation in practice.
Landfilled waste and waste management	Examination and specification of the reactions which occur in the landfilled waste, with due consideration for the various types of waste which are landfilled separately or together; the development of fast and simple analytical processes for assessing the delivered waste and methods of waste management; controlled structuring of the landfilled waste in the desired quality, forecasting of the waste landfill's behavior; examination of the landfill's behavior; development of appropriate examination methods.
Landfill sealing systems	The further development of sealing systems for waste landfills is a special area requiring research, in order to prevent emissions (gaseous and liquid) from landfills. Research topics are: - subsequent sealing measures - production and installation measures for various sealing materials - development of control mechanisms for the quality of the sealing systems - the long-term behavior of the sealing systems.

TABLE B-3 AREAS OF FUTURE BMFT-SPONSORED R&D IN ER (Cont.)

Risk analysis	The development of concepts for risk and reliability analysis relating to the emission behavior of the waste landfill, stipulation of the requirements concerning the environmental compatibility of the landfill and examination of these in practice.
UNDERGROUND LANDFILLING	
Investigation of the long-term effectiveness of natural barriers in the area of underground landfilling Questions relating to the selection and assessment of sites Processes for pre-treatment of the waste Processes for depositing the waste (e.g., in caverns) Success-verification methods and monitoring methods	
ABANDONED HAZARDOUS SITES	
Identification and examination measures	The development and testing of processes to localize, identify and examine abandoned industrial sites and abandoned waste disposal sites.
Risk assessment	The development and testing of risk assessment processes for potential hazardous sites (assessment of the risks to groundwater, surface water, air, soil and buildings); stipulation of assessment guidelines and assessment models, with due consideration of local, geological factors.
Environmental compatibility	Examination of the environmental compatibility of the respective remediation processes and the development of concepts for treatment of the resultant residues and for utilization of the purified soils, e.g. examination of the leachability of thermally treated soils.
Process optimization	The development and optimization of new remediation processes, also including combined processes.
Biological processes	The further development of biological remediation methods; the decomposition of higher aromatics by bacteria; optimization of the chemical environment; improvement of fluid mechanics in soils; development of testing processes to monitor success; examination of the ecotoxicological and, in particular, the human-toxicological effects of possible metabolites.
Special processes	The development of special processes: - Processes for the remediation of developed areas; - Processes for the treatment and remediation of remnants explosives and soil contamination from former production works of the arms industry
Data bases	Collection of the results of the research work in data bases and the development of expert systems.

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TABLE B-4. USEFUL ADDRESSES AND PHONE NUMBERS

Abwassertechnik, Abfalltechnik + Recycling
(Waste Water, Waste Disposal + Recycling)
Postfach 14 to 60
6200 Wiesbaden

Telephone: 612179 10
Telefax: 612179 12 85

Budesminister fuer Umwelt, Naturschutz und Reaktorsicherheit
Kennedyallee 5
Postfach 120629
W-5300 Bonn 1

Telephone: 228 305 2240

Deutsche Forschungsanstalt für Luft- und Raumfahrt e.V. (DLR)
Projektträger "Umweltschutztechnik"
Südstraße 125
W-5300 Bonn 2

Telephone: 228 38210
Telefax: 228 3821 229

Federal Health Ministry
Bundesminister für Gesundheit
Deutschherrenstraße 87
Postfach 200129
5300 Bonn 2

Forschungszentrum Jülich GmbH (KFA)
Postfach 1913
W-5170 Jülich 1

Telephone: 246 1610

Fraunhofer Institut für Unweltchemie und Oekotoxologie
(Fraunhofer Institute for Environmental Chemistry and Eco-Toxology)
Postach 12 60
5948 Schmallenberg

Telephone: 2972 3020
Telefax: 2972 3023 19

Gesellschaft für Biotechnologische Forschung (GBF)
Mascheroderweg 1
W-3300 Braunschweig-Stockheim

Telephone: 531 61810

Gesellschaft für Strahlen- und Umweltforschung mbH (GSF)
Ingolstädter Landstraße 1
W-8042 Neuherberg
Post Oberschleißeim

Telephone: 89 31871

With institutes in Neuherberg and München, Attaching, Clausthal-Zellerfeld, Dortmund, Frankfurt, Göttingen, Grünbach, Hannover, Wolfenbüttel

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Treuhandanstalt
Leipziger Straße 5-7
0-1080 Berlin

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Telefax: 30 3154 1348

TABLE B-4. (CONT.) USEFUL ADDRESSES AND PHONE NUMBERS

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Karlsruhe (GmbH (KfK)
Projektträger "Wassertechnologie und
Schlammbehandlung"
Postfach 3640
W-7500 Karlsruhe 1

Telephone: 7247 82 4851
Telefax: 7247 82-2377

Kreditanstalt fuer Wiederaufbau
Palmengartenstrasse 5-9
W-6000 Frankfurt/Main

Telephone: 69 743 11

Müell und Abfall
(Garbage and Waste Disposal)
Erich Schmidt Verlag GmbH
Postfach 73 30
4800 Bielefeld 1

Telephone: 521 58 30 856

Sächsisches Staatsministerium
Für Umwelt und Landesentwicklung
Ostra Allee 23
0-8010 Dresden

Telephone: 37 91 4860202

Senator Für Wirtschaft und Technik
Berlin
Martin Luther Straße 105
W-1000 Berlin 62

Telephone: 30 7831
Telefax: 30 783 8455

Senatsverwaltung Für Stadtentwicklung
Und Umweltschutz
Lindenstraße 20 - 25
W-1000 Berlin 61

Telephone: 30 25860
Telefax: 30 25 86 23 98

Umwelt (VDI)
(Environment)
Graf-Recke-Str. 84
4000 Duesseldorf 1

Telephone: 211 62 141
Telefax: 211 62 14 575

Umweltbundesamt (UBA)
Projektträger "Abfallwirtschaft und
Altlastensanierung"
Bismarckplatz 1
W-1000 Berlin 33

Telephone: 30 89 032275

Umweltmagazin
(Environmental Magazine)
Vogel-Verlag
Max-Planck-Str. 7
8700 Wuerzburg

Telephone: 931 41 80
Telefax: 931 44 053

Umweltministerium
Des Landes Brandenburg
Albert Einstein Straße 42-26
0-1561 Potsdam

Telephone: 37 33 3160

Umweltministerium
Des Landes Mecklenburg-Vorpommern
Schloßstraße 6-8
0-27ß0 Schwerin

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Umweltministerium
Des Landes Sachsen-Anhalt
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0-3024 Magdeburg

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