# CONTAMINATED SITES AND ENVIRONMENTAL CLEANUP

*International Approaches to Prevention, Remediation, and Reuse*

G. WILLIAM PAGE

CHAPTER 1

# THE PROBLEM OF CONTAMINATION AND ENVIRONMENTAL CLEANUP

## INTRODUCTION

This chapter outlines the general problem of contaminated sites and environmental cleanup and discusses the characteristics and sources of toxic substances contamination that cause the potential threats to both human and ecosystem health. A historical case study in the United States demonstrates how economic forces created this environmental problem, which has become an important political issue in many countries.

### *Defining the Problem*

The term "contaminated sites" refers to parcels of land on which or under which hazardous and toxic substances exist under conditions that do not effectively confine their movement. The "toxic time bombs" or "toxic hot spots" that the media often refer to are the worst examples of contaminated sites, many of which are former hazardous waste disposal sites. Many thousands of other sites have less extensive toxic contamination, but they are also part of the contaminated sites and environmental cleanup problem. The toxic substances found at contaminate sites threaten human and ecosystem health in the present as well as in the future. The enormous cost of environmental cleanup contributes to the abandonment of many contaminated sites and the subsequent failure to return them to productive use. Cleaning up sites often costs far more than the value of the land.

There are large numbers of contaminated sites in all the economically developed countries and comparatively fewer in other countries. Most of these contaminated sites are the legacy of many decades of industrial development and military activities. The United states has approximately 600,000 sites contaminated with toxic substances, although many of these may not represent a serious human health threat (Office of Technology Assessment, 1983). Estimates for the number of suspected contaminated sites in The Netherlands range from 200,000 to 600,000 (Soczó *et al.*, 1992; Business Roundtable, 1993). In Germany, there are 250,000 suspected contaminated sites (Franzius, 1992). In the United Kingdom, there are 50,000–150,000 suspected contaminated sites comprising from 50,000 to 250,000 hectares (123,550 to 617,750 acres) of contaminated land (Denner, 1992a).

The major cause of such contamination is the production of large volumes of toxic substances in modern industrial and postindustrial societies. Most countries use toxic substances in many industrial processes, including those associated with defense industries, manufacturing, agriculture, and the production of commercial and household products. Table 1.1 presents data that are rough approximations of the hazardous waste

### TABLE 1.1

#### INTERNATIONAL HAZARDOUS WASTE GENERATION[a]

| Nation | Year of data | Amount (tons) | Amount per capita (tons) | GNP per capita ($) |
|---|---|---|---|---|
| Switzerland | 1987 | 300,000 | 0.05 | 21,000 |
| United States | 1985 | 583,000,000 | 2.3 | 17,000 |
| Japan | 1983 | 1,540,000 | 0.01 | 16,000 |
| West Germany | 1988 | 7,150,000 | 0.1 | 15,000 |
| Canada | 1983 | 3,500,000 | 0.2 | 14,000 |
| France | na | 19,800,000 | 0.4 | 13,000 |
| Austria | 1984 | 2,700,000 | 0.4 | 13,000 |
| Denmark | 1985 | 154,000 | 0.03 | 11,000 |
| Italy | 1988 | 5,000,000 | 0.09 | 10,500 |
| Netherlands | 1987 | 580,000 | 0.04 | 9,000 |
| United Kingdom | 1988 | 5,500,000 | 0.1 | 8,000 |
| Belgium | 1988 | 1,650,000 | 0.2 | 8,000 |
| Hungary | 1986 | 2,000,000 | 0.2 | 7,500 |
| Average | | | 0.2 | |

[a]Modified from Schwab (1993).
These data are rough approximations only, because of data differences.



produced in several industrialized nations. The quality and comparability of these data vary. For instance, the value of 2.3 tons per capita for the United States is more than twice other estimates of 1 ton for each man, woman, and child (Barnett, 1994). Nonetheless, the table does provide interesting comparisons. Even for countries with relatively comparable gross national product (GNP) per capita, there is surprising variation in hazardous waste production.

In most cases, gradual releases of toxic substances cause contaminated sites. Many people think that catastrophic single events, such as a fire at a plant, a spill of chemicals, or an illegal discharge such as "midnight dumping," are the common causes of contaminated sites. These events certainly do result in contaminated land. However, the gradual release of toxins to the environment through a routine discharge or leak over a long period of time cause the vast majority of contaminated sites.

Some activities that cause contamination are outside the obvious activities in a modern manufacturing/consumer society. Mining operations produce large quantities of toxic wastes. About 95% of the total material

### TABLE 1.2

#### TYPES OF SITE AND CONTAMINATION AT U.S. SUPERFUND SITES[a]

| Type of site or contamination | Percentage of sites |
|---|---|
| Abestos | 1 |
| Battery recycling | 1 |
| Industrial landfill | 11 |
| Metals | 6 |
| Metals/organic chemicals | 16 |
| Mining waste | 3 |
| Municipal landfill | 9 |
| Munitions | 1 |
| Organic chemicals | 15 |
| Polychlorinated biphenyls (PCBs) | 6 |
| Pesticides | 7 |
| Metal plating | 5 |
| Radioactive waste | 1 |
| Solvents | 11 |
| Wood preserving | 2 |
| Multisource groundwater | 5 |
| Total | 100 |

[a]Modified from U.S. General Accounting Office (1993, Table 2.1).

removed in mineral extraction is waste that often contains heavy metals. Defense facilities have created numerous contaminated sites through fuel spills and weapons production wastes. By 1991, the U.S. Department of Defense had identified 17,660 sites with potential toxic contamination of soil or groundwater (Rose, 1994). The U.S. Department of Energy is responsible for the environmental cleanup of perhaps 30% of the country's most serious contaminated sites, which became contaminated through nuclear weapons and research operations (Bredehoeft, 1993).

Some contaminated sites exist from long before modern industrial activity. Tanneries and printing operations dating from the Middle Ages produced contaminated sites that are still a problem today. Gas works operating 100 year ago in many European cities produced volatile aromatic hydrocarbon, polynuclear aromatic hydrocarbon, and cyanide contamination (see the Tilburg Gas Works Case Study in Chapter 10).

A review of data concerning the contaminated sites in the U.S. Superfund program provides insight into the types of sites and their constituent contaminants. Investigators examined 149 Superfund sites at which environmental cleanup was complete or nearly complete in 1993 and found a wide variety of contamination types and sources (Table 1.2).

## CHARACTERISTICS OF TOXIC CONTAMINATION

Several definitions are necessary to understand the problem of contamination and environmental cleanup. A "toxic" substance is dangerous to human health, usually depending on the precise level of concentration, compounding, or ionization of the chemical. A "hazardous" substance includes those with any one of the following four characteristics: toxicity, corrosivity, flammability, or reactivity. The distinction between pollution and contamination is also useful. Both terms refer to unwanted, human-caused changes in the physical, chemical, or biological characteristics of the natural environment. For the purposes of this book, pollution refers to substances released to the environment in the present, whereas contamination refers to an existing condition resulting from pollution at a previous time. Thus someone spilling used motor oil on the ground is creating pollution. If no one contains or removes the spilled oil from the soil, it becomes contamination. Since several toxic substances are present in used motor oil, the land on which someone spills oil becomes "contaminated land."

Not all contamination is the same. Contamination with toxic substances has some properties that are different from those of other types of contamination. Unlike conventional pollutants, many toxic substances are extremely persistent in the environment and a threat to human and ecosys-



tem health at low levels of exposure. These long-lived toxic chemicals may be heavy metals, radioactive substances, or organic chemicals with toxic properties. Natural processes can disperse and degrade conventional pollutants in relatively short periods of time. For example, the discharge of domestic sewage to water bodies or the release of conventional pollutants to the atmosphere is ameliorated by the activity of bacteria, dispersion, and other natural processes. In contrast, toxic substances contamination in the environment may remain a serious problem for long periods, even if no additional pollution occurs.

The persistence of toxic substance contamination is critical to understanding the contamination and environmental cleanup problem. Heavy metals such as lead and mercury are primary chemical elements that will never degrade. The persistence of radioactive substances varies greatly, but some highly toxic radionuclides are extremely persistent. For instance, plutonium-239 has a half-life of 24,100 years (Eisenbud, 1987, Appendix). Some organic chemical compounds are chemically stable and therefore resistant to environmental degradation. Several developed countries ban the use of some of the most persistent pesticides, such as the heavily chlorinated hydrocarbon DDT. Highly persistent toxic chemicals are a special threat to ecosystems and human health. From the present until far in the future, they may migrate through poorly understood environmental pathways and thereby expose additional ecosystems and humans. Some of these toxic substances tend to bioaccumulate in the food chain.

The health risk of some toxic substances changes when human activities release them on the land or into the ground. Sunlight and exposure to oxygen increase the rate of degradation of many organic chemicals. Once organic compounds are in the soil or groundwater, they may have protection from such exposure, which can increase their persistence and thus the potential for human health and ecosystem damage.

Though industrial activity, nuclear energy, and the military have caused the greatest amount of contaminated land in densely developed areas, other activities can also cause contaminated sites. Even activities that release only small quantities of toxic chemicals are a problem, for many chemicals are toxic at extremely low levels of exposure. Evidence suggests that some toxic substances cause cancer at exposures of a few parts per billion or less. This means that it is potentially possible for a few gallons of toxic waste to contaminate billions of gallons of groundwater. Such contamination can be high enough to produce cancer in humans who drink the water over a lifetime.

Small quantities of toxic waste are significant dangers and many small commercial establishments and households can cause extensive and dangerous contamination. Dry cleaners, chrome platers, and diverse machine shops, printers, and others that use solvents have the potential to seriously contaminate soil and groundwater. Household wastes, including used motor oil, paints and thinners, cleaners, lawn care products, and other goods, contain toxic substances that can cause contamination. Mining, agriculture, and other activities also result in extensive toxic contamination of land. This book concentrates on sites contaminated from industrial sources in urban areas that threaten exposure of large human populations. However, environmental policy to deal with contaminated sites must apply to all contaminated sites regardless of location or source of contamination.

Contaminated sites themselves are only the beginning of the problem of toxic contaminants released to the natural environment. Once free in the environment, toxic substances can follow environmental pathways and tend to accumulate in what scientists refer to as "environmental sinks." Wetlands and the sediments at the bottom of rivers, estuaries, and harbors are such environmental sinks for toxic substances. In the Great Lakes region of North America, the International Joint Commission representing the United States and Canada has identified 362 different toxic chemicals in river and harbor sediments. These locations are the overwhelming majority of the "toxic hot spots" designated for remedial action.

The policy debate must be considered in a historical framework, because much of the toxic pollution that created today's contaminated sites occurred in past decades. Economic factors, public awareness of environmental issues, knowledge of the health effects of microcontaminants, and environmental legislation have changed over time. For decades when we had less knowledge of environmental hazards, industry routinely used many toxic or hazardous substances in ways that we now know caused contamination. Because society did not recognize the threat of toxic substances contamination, standard operating procedures for the use and disposal of materials and waste products were lax compared to today's environmental regulations. In the past, we did not realize that policies implemented to prevent toxic pollution are much more effective at protecting the environment and public health than policies to promote environmental cleanup. The former are also much less expensive than policy implemented to remediate toxic substances contamination.

In many developing countries with less experience with toxic contamination, environmental legislation is still lax compared to that of the United States and other economically developed countries. As the developing countries assume a rapidly increasing proportion of the world's industrial activity, they risk creating large contamination and environmental cleanup problems. Some developing countries are implementing or considering innovative policies to control hazardous wastes and prevent contaminated sites (see the discussion of Thailand's approach in Chapter 7).



## CONTAMINATION AND ENVIRONMENTAL CLEANUP EXPERIENCE IN THE UNITED STATES

The following case study of the U.S. experience provides historical context to the problem of contamination and environmental cleanup. The United States is a useful case study because it has been at the forefront of environmental science and environmental policy over the past several decades. It was the first to identify contaminated sites as a serious problem and to develop innovative policies. Many of the most economically developed countries have only recently formulated policies to address contamination and environmental cleanup (Table 1.3).

The U.S. Superfund program is at the center of the policy debates about remediating contaminated sites. There are presently about 2000 sites on the program's National Priority List for cleanup. Approximately four million Americans live within one mile of a Superfund site and more than 40 million Americans live within four miles (National Research Council, 1991, p. 2). Over the next 30 years, researchers estimate that the United States will spend \$400 billion to \$1.7 trillion in remediating contaminated sites (Russel *et al.*, 1991). Superfund is a controversial program that has not solved the problem of contaminated sites and environmental cleanup, and the program's costs far exceed expectations. Policies for remediating contaminated sites controlled by the Departments of Energy and Defense continue to evolve, but are less successful at remediation than the Superfund program.

### TABLE 1.3

#### INITIATION OF POLICY APPROACHES TO CONTEND WITH CONTAMINATED SITES

| Country | Year | Source |
|---|---|---|
| United States | 1976 | See Chapter 1 |
| Netherlands | 1980 | Visser (1993, p. 45) |
| Germany | 1981 | Kingsbury and Bingham (1992, p. 248) |
| Finland | 1981 | Visser (1993, p. 67) |
| Denmark | 1983 | NATO/CCMS (1992, p. 4) |
| Switzerland | 1983 | Visser (1993, p. 73) |
| Sweden | 1985 | Kingsbury and Bingham (1992, p. 191) |
| Norway | 1988 | Folkestad (1992) |
| Austria | 1989 | Kasamas (1992) |
| Canada | 1989 | Hill (1992) |
| France | 1989 | Goubier (1992) |
| United Kingdom | 1990 | Denner (1992b) |

Prior to the heightened awareness of environmental problems in the 1970s, the United States exerted little control over the use and disposal of toxic substances. For example, the U.S. Solid Waste Disposal Act of 1965 and the Resource Recovery Act of 1970 treated the disposal of toxic and hazardous materials no differently than other waste products. Industry sent most waste to land disposal sites that were not designed to keep toxic and hazardous materials from escaping into the environment. Some land disposal sites were commercial or municipal landfills, but many were private disposal sites operated by an industry on the same property as the production facility.

Toxic substances pollution was and remains a serious problem in the United States. The Environmental Protection Agency (U.S. EPA) estimated that in the 1970s industry sent about 240 million tons of solid industrial wastes to land disposal sites each year. As much as 15% of this waste was hazardous (U.S. Environmental Protection Agency, 1977a,b). Annual waste production in the 1970s included 1700 billion gallons of liquid wastes that were pumped to some form of surface impoundment (Russell, 1978). A U.S. EPA survey of surface impoundments at the time found that the large majority were unlined with any material that might keep waste products from percolating into groundwater (U.S. Environmental Protection Agency, 1978). The U.S. government estimated that before the 1970s industries improperly disposed of 90% of all hazardous wastes in open pits, surface impoundments, vacant land, farmlands, and water bodies (U.S. Environmental Protection Agency, 1974).

Inadvertent leaks during transport, storage, or use can also create contaminated sites. Until the mid-1970s, U.S. firms annually released additional huge quantities of toxic and hazardous materials to the ground from leaking underground storage tanks and from accidental spills and leaks. Even after years of increasingly stringent regulation, EPA estimated that there are several million underground storage tank systems that contain petroleum or other hazardous substances and that as many as 25% of them leak (Evans, 1988). It is important that local governments in all countries have well-developed emergency preparedness plans to respond to the inevitable accidental spills and leaks of hazardous materials (United Nations Environment Programme, 1992; Organization for Economic Cooperation and Development, 1991).

It is widely believed that the free market economic system in the United States maximizes economic benefits to the nation. This assumes that if each firm and individual attempts to maximize their own self-interest, then the aggregate of this behavior will produce the greatest benefit to the nation. Prior to the increase in environmental awareness of contaminated sites in the mid-1970s, private firms maximized their private benefit.



Under then existing laws, firms could use, store, and dispose of toxic substances in ways that minimized costs. Unfortunately, these activities caused substantial toxic pollution. The aggregate benefit of this behavior was not socially or economically optimal because individual decisions did not include consideration of the true costs of pollution. The cost of remediating contaminated sites today is many times greater than the cost would have been to have proper controls on toxic substances at the time they polluted the environment.

In the United States, the private market economic system imposed no disposal costs on firms that dumped their toxic and hazardous wastes on or into the ground of their own property. Very few data for on-site disposal activities are available. For this reason, we do not have an accurate inventory of contaminated sites. Some firms know that contamination exists on their property, but they do not want that knowledge to become public. Without publicly acknowledging the contamination, some firms leave large portions of their property undeveloped and often erect fences to keep their employees and the public off the property. Often, the only way the public or government agencies can learn of contaminated private land is if the firm places the property on the real estate market. Real estate transactions for industrial land today require environmental assessments to discover if toxic contamination is present.

## CONTAMINATION AND ENVIRONMENTAL CLEANUP BECOME A POLITICAL ISSUE

As mentioned earlier, in the 1970s the public awareness of toxic contamination grew in the United States. The residential neighborhood known as Love Canal in Niagara Falls, New York, was the single most notorious case to heighten such awareness. Before the Love Canal episode, the general public was not aware of the explosive growth in the production of new chemical compounds since World War II. Nor did the public realize that people could be unknowingly exposed to these chemicals because they were so poorly controlled, or that many of these chemicals were a threat to human health at levels of exposure that they could not see, smell, or taste. Love Canal dramatically changed the public's perceptions. Analogous cases of contaminated sites are the village of Lekkerkerk (see Chapter 10) and the Merwedepolder housing project in Dordrecht (Kingsbury and Bingham, 1992), both in The Netherlands.

From 1942 to 1953, the Hooker Chemical and Plastics Corporation had buried 22,000 tons of chemical waste in canals on its property. In the early 1950s, the company filled the canals, subdivided the property, and began selling the contaminated land. Developers bought the property and built a residential neighborhood known as Love Canal on this former chemical waste disposal site. By the mid-1970s, the media started reporting complaints by the residents of the Love Canal neighborhood about strange health problems that they attributed to the contaminated land (Leonard *et al.*, 1977). Health studies reported disturbing findings of cell aberrations and implications of increased risks of cancer, birth defects, and spontaneous abortion (New York Department of Public Health, 1978; Picciano, 1980; Deegan, 1987).

In August 1978, government officials declared the area unsafe. They evacuated 1004 households from the Love Canal area and spent $30 million purchasing homes in the most contaminated areas. Extensive publicity about Love Canal dramatically raised the public's perceptions of the problem of contamination and environmental cleanup.

Resolution of the legal actions concerning over Love Canal continued for many years. In June 1994, Occidental Chemical Company, the successor corporation to Hooker Chemical, agreed to pay $98 million to the state of New York for the state's part in the cleanup. This payment ended a 14-year-long lawsuit. In 1995, Occidental agreed to pay the U.S. EPA $129 million as settlement for EPA expenses at the Love Canal site.

Another example of a contaminated site that gained wide notoriety was the Valley of the Drums in Bullitt County, Kentucky. In 1975, investigation of the uncontrolled industrial waste dump in a rural, 13-acre valley found over 17,000 drums, many of them filled with hazardous waste. Deteriorated and leaking drums had released 140 different chemical compounds, including heavy metals, polynuclear aromatic hydrocarbons, and polychlorinated biphenyls (U.S. Environmental Protection Agency, 1992), and contamination was entering Wilson Creek, a tributary of the Ohio River. The devastation to the natural vegetation of the site made a powerful image of the ecological cost of toxic contamination.

Media coverage of such cases produced rapid and intense public concern. Researchers who investigated the flagship news programs of ABC, CBS, and NBC found that, between 1978 and 1987, the networks ran 99 Love Canal news stories that used 191.2 minutes of prime time television (Greenberg and Wartenberg, 1990). In addition to the cases of contamination and environmental cleanup that made national news, most regions of the United States also had media coverage of local contamination problems. For example, in Buffalo, New York, citizens discovered that the city had built a neighborhood playground on arsenic-contaminated soil (Thigpen, 1993). In all cases, the public demanded action from public officials.



## CONCLUSIONS

The contamination and environmental cleanup problem requires three policy approaches: (1) take immediate action to protect the health of people at risk because of proximity to contaminated sites; (2) stop additional pollution from creating additional contaminated sites; and (3) clean up contaminated sites to render them environmentally healthy and available for productive uses.

Several countries have recognized the importance of this problem and have developed policies that attempt to solve it. All of these policy approaches have had some success in protecting people and ecosystems, stopping additional toxic pollution, and implementing environmental cleanups. However, no country has yet developed policies that completely eliminate the problem; contamination is too extensive and cleanup is too expensive.

The next three chapters cover the aforementioned policy approaches. Chapter 2 discusses the techniques used to achieve environmental remediation; Chapter 3 addresses exposure, toxicity, and risk issues regarding proximity to contaminated sites; and Chapter 4 discusses how to prevent additional contaminated sites.

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