Impact of Hazardous Waste on Human Health
Hazard, Health Effects, Equity, and Communications Issues

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Acknowledgments

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About the Author

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With apology to the work of Charles Dickens, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) is the worst of laws; it is the best of laws. Within these two extremes lies a predictably vast span of opinion about CERCLA's importance. Much less debatable, however, is the proposition that CERCLA is the single most controversial federal environmental statute. Why is this? And where are the "worst" and "best" of this much maligned statute, also known as the Superfund law?

As a brief background, the U.S. Congress enacted CERCLA in 1980, and President Carter signed it into law. Predicate events that shaped the statute included widespread media attention about abandoned hazardous waste dumps leaking into homes in Love Canal, New York, and the discovery of thousands of leaking, buried drums of chemicals in Kentucky, the so-called "Valley of the Drums." The public expressed great concern that chemicals released from such sites would cause human health problems. By enacting CERCLA, Congress acted on this concern to protect human health and prevent further damage to natural resources and environmental quality.

The news media quickly named the new statute "Superfund" because the law established a multibillion dollar trust fund. The trust fund was created by a tax on segments of private industry. Other revenue was to be generated by granting broad authority to the federal government to identify parties responsible for the waste in a particular waste site and to require these "potentially responsible parties" to pay for cleanup costs. The issue of who pays and in what amounts quickly forged an outpouring of litigation from parties great and small. Costs of litigation and the statute's mandate to assess blame further fueled discontent and confrontation between government and the private sector. All this, in turn, has led to numerous criticisms of the statute and occasionally some praise.

An observer looking for the "worst" of CERCLA has ready access to a mountain of material. Consider only the congressional debates that attend periodic attempts to reauthorize CERCLA. Criticisms abound from disparate sources. For example, some private industry sources assert that costs for remediating uncontrolled hazardous waste sites (i.e., CERCLA sites) are too great, are unfairly parsed among responsible parties, and are incommensurate with the health risks posed by the sites. On the other hand, some grassroots community groups voice concerns that sites take too long to be remediated, economic impacts of diminished property values are unaddressed, and adverse health effects in CERCLA communities are inadequately examined. Media crit-

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1 Uncontrolled hazardous waste sites are distinguished in federal law from operating, permitted, hazardous waste management facilities. CERCLA covers the former; the Resource Conservation and Recovery Act covers the latter.
ics also abound, noting that, in their reckoning, too few CERCLA sites have been struck from the National Priorities List. Many of these criticisms have merit, regardless of their source, but as with any criticism, there is usually much more to the story.

Many would aver that an observer looking for the "best" in CERCLA will find significant outcomes and benefits from the statute and its attendant programs. Several hundred hazardous waste sites have been remediated, emergency responding has been enhanced through community preparedness and response actions, a large number of public health actions have occurred in communities near waste sites, and toxicologic and other scientific databases have been advanced. National environmental organizations have been active supporters of CERCLA because it fits into their agenda for reducing the impact of environmental hazards, in general, and the effects of toxic substances, in particular. And some grassroots environmental organizations have actively supported CERCLA because it is the only supply of resources and authorities that deal directly with uncontrolled hazardous waste sites. Also, over time, some private industry organizations and state and municipal governments have voiced support of CERCLA's intent of environmental remediation and protection of human and ecologic health.

As a person involved in the public health aspects of CERCLA since 1986, I believe much good has been accomplished, although not without errors and poor judgments in both the law's content and its administration. Clearly CERCLA has brought the problem of hazardous waste generation and management onto the agenda of environmental and public health agencies. Absent CERCLA, very little attention would be paid to the problem of abandoned hazardous waste in the environment and what to do about it. This is because many other environmental priorities are perceived by some as having higher priority. Furthermore, CERCLA has made substantial contributions to a better understanding of the effects hazardous substances have on humans and ecosystems. Similarly, knowledge about how to clean up hazardous wastes would still be marginal without the statute.

Given the divergence of opinion about the worth of CERCLA, it would be impossible in one work to address all the points of contention. It is possible, however, in a single volume to address one point of contention: To what extent do hazardous wastes deleteriously impact human health?

What then is the impact of hazardous waste and waste sites on human health? Again opinion is divergent. Statements from some members of Congress, buttressed by opinions and data from some risk assessors, conclude that CERCLA sites have a small impact. On the other end of the scale, other members of Congress and some grassroots environmentalists assert that major health problems are attributable to CERCLA sites. Where lies the truth? Moreover, is the question of human health impact really relevant? Can't sites simply be cleaned up as resources permit and won't that be enough to assuage health concerns?

This work will attempt to provide a data-based response to the foregoing questions. Many of the health data described in this book have been collected or commissioned by the Agency for Toxic Substances and Disease Registry (ATSDR), the federal public health agency established in 1980 by the CERCLA statute. Also, a substantial amount of environmental contamination data is presented, largely collected by the U.S. Environmental Protection Agency (EPA). This book is intended as a successor to earlier scholarly works by persons concerned about the human health implications of mismanaged hazardous waste. In particular, I refer to the following works as key antecedents to this book: J.B. Andelman and D.W. Underhill, *Health Effects from Hazardous Waste Sites*; J.

In many ways it is unfortunate that the CERCLA statute, because of its controversial nature, has become a program focused almost exclusively on site cleanups and litigation. What gets lost in this kind of calculus is the considerable body of improved scientific data, improved risk assessment methods, and positive impacts on community health that have resulted over the years of the CERCLA statute. When funds are redirected away from science and human health programs into litigation and other transactional costs, the public will ultimately be the poorer for this *de facto* de-emphasis of health issues. Stagnant environmental and toxicologic science and less clear impacts on human health will be the result.

The chapters that follow will provide up-to-date depictions of the human health impacts of hazardous waste and attendant public health responses. I hope this work will be useful to policy makers, environmentalists, toxicologists, public health officials, academicians, health care providers, and community-based organizations. That was my goal.
The Book's Structure and Themes

This book describes the association between hazardous waste and human health and the role of public health programs in addressing this association. As stated in the Preface, this is intended for use by policy makers, environmentalists, toxicologists, public health officials, academic personnel, and health care providers. Because this is a broad and diverse audience it is important to make clear certain key definitions of terms used throughout the book. One key definition needed is "public health," a term most Americans have a sense of, but probably cannot define. Indeed, it may be surprising that no single, operative definition is used by all public health agencies. The following are cited as illustrations of the diverse definitions of public health.

Definition of Public Health

The Institute of Medicine is a component of the National Academy of Sciences. The U.S. Congress created the academy in the middle of the nineteenth century to advise federal government agencies on matters of science. The Institute of Medicine (IOM) focuses on medical science and practice. In 1988 the IOM constituted a Committee for the Study of the Future of Public Health, which reviewed the current status and future of public health in the United States and produced the report, The Future of Public Health (IOM, 1988). As part of their work, the IOM's committee developed a definition of public health, dividing it into three parts: mission, substance, and organizational framework:

The committee defines the mission of public health as: the fulfillment of society's interest in assuring the conditions in which people can be healthy.

The committee defines the substance of public health as: organized community efforts aimed at the prevention of disease and promotion of health. It links many disciplines and rests upon the scientific core of epidemiology.

In summary, the committee defines the organizational framework of public health to encompass both activities undertaken within the formal structure of government and the associated efforts of private and voluntary organizations and individuals.

The IOM's committee therefore chose to define public health in terms of its perceived components. This was purposeful for the committee's work, but seems to beg the question of defining public health more prescriptively.

Gordon and McFarlane (1996) define public health as: "The art and science of preventing disease and disability, prolonging life, promoting the health and efficiency of populations, and ensuring a healthful environment through organized community efforts." This definition is more coherent than the IOM statement, and brings together the concepts of science, quality of life, health promotion, and community effort.
However, the definition by Detels and Breslow (1991) is preferred for this book. They state, "Public health is the process of mobilizing local, state, national, and international resources to solve the major health problems affecting communities." This definition is appealing because it promotes the ideas of partnership, communities, and action—all of which are themes in this book.

Several points should be noted in the Detels and Breslow definition. Public health is a process; that is, a system of understood ways of addressing problems. Public health mobilizes resources, bring together various agencies or groups in a common cause to prevent or eradicate a community health problem. Public health begins and ends at the local level. Disease outbreaks occur locally and communities expect local authorities to solve their health problems. Public health involves cooperative interaction and sharing of resources across lines that extend from local to international agencies. This intersectoral approach to public health has become increasingly important because of international trade and travel. The AIDS epidemic is an example. Depletion of the earth's protective ozone layer is another example. For the most part, public health solves major health problems. Trifling and low-significance problems receive little or no public health response. This book takes the view that hazardous waste problems are major hazards to the public's health.

Public health is generally not the means for providing an individual's personal health care, at least not in the United States. Most clinical medical care is provided by community physicians and other health care providers, local hospitals, and private health insurance providers. Some local public health agencies, however, do provide some health care for indigent populations; for example, community health centers provide prenatal care for pregnant women.

Public health in the United States is organized along levels of government. Federal public health programs are found in the Department of Health and Human Services (DHHS). State programs are lodged in state health departments, and local public health services are located in county or city health departments. Regarding hazardous waste problems, each level of government can, and often does, get involved. Local health departments are frequently the first place where community residents express their concerns about an abandoned waste site or a toxic substance. The response to chemical spills always involves hazardous materials (HazMat) teams. These teams are most often found in fire or police departments but can involve local health departments as well (Chapter 6). State health departments get involved with hazardous waste issues through interaction with federal and state Superfund programs. Health departments of some states work with local health departments to give local health care providers training and education on matters of hazardous substances and waste issues. Federal health agencies provide technical assistance (e.g., epidemiologists) and financial and personnel resources to state and some local health departments, in response to communities' health concerns about hazardous substances.

Themes in the Book

This book is about one specific environmental hazard, hazardous waste, and its impact on human health. Several themes will characterize the material in subsequent chapters as a coherent body of knowledge. These themes are the product of both the author's experience as a public health officer and the science and findings to be described throughout the book. There are six primary themes in this book, as follows:
1. The large number of uncontrolled hazardous waste sites present in the United States is a major human health hazard. Although the precise nature and extent of the impact of waste sites on human health is difficult to quantify, the CERCLA program on human health effects has produced sufficient epidemiologic and toxicologic findings to warrant serious concern for the effects of substances released from uncontrolled waste sites on the public's health.

2. It is not only possible, but essential, to set priorities for risk management actions (e.g., site remediation) at uncontrolled waste sites on the basis of their hazard to human health. Indeed, prioritization is a key concept throughout this book. It is possible to rank sites on the basis of health hazard, to prioritize substances released from sites on the basis of toxicity, and to rank putative health effects caused by human exposure to substances released from sites.

3. Risk management actions at CERCLA sites must include more than simply interdicting any ongoing human exposure to substances released from sites. The trend has been to consider the CERCLA statute and its resources as merely a site remediation program. While interdicting releases of hazardous substances from sites is surely the first step in any effort to prevent further hazard to human health, other actions must also be taken when human exposures have been documented. These actions include educating physicians and other health care providers in communities impacted by releases of substances from sites, communicating health risks in ways that empower communities, characterizing exposure of persons at a health risk, and conducting health surveillance and health promotion (including medical monitoring when warranted) to identify any early signs of illness or disease.

4. Prevention should be the operative word and action in any program intended to reduce the toll of hazards on human health and ecologic systems. The public health literature abundantly documents that preventing a disease is less costly than treating it. This adage applies equally well to environmental hazards. Preventing the production of hazardous waste through industrial recycling or preventing contact with any generated hazardous waste will obviously lessen any adverse effects on human health or the ecosystem. Even when hazardous waste has been produced and released into the environment, early interdiction of contact with the released substances can help minimize or prevent subsequent human health effects.

5. Partnerships are required if the legacy of uncontrolled hazardous waste is to be effectively counteracted. Government, community, business and industry, and academia are all needed if cost-effective, responsible means for protecting the public's health and the environment are to be achieved.

6. The best science must be applied to the environmental health and remediation challenges presented by uncontrolled waste sites and similar sources of environmental contaminants. The combination of hazardous substances released from waste sites or through unintended release (e.g., chemical spills) and their conditions of release present severe challenges to scientists. The toxicology of many substances commonly released from waste sites is often incomplete, and the toxicology of mixtures of substances is even more dimly understood. Yet costly remediation actions at sites and well-intended health responses for communities exposed to substances must be predicated on the best current scientific knowledge and should not be forestalled because of inadequate science. Indeed, nothing should prevent the allocating of financial and personnel resources to conduct the science necessary to improve site risk assessments and population-based health actions.
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Chapter One

Nature and Extent of Hazardous Waste

How many uncontrolled hazardous waste sites are there in the United States and what will be the cost of their remediation (i.e., cleanup)? What are the broad characteristics of these sites, and where does the public rank the health hazard of hazardous waste sites? Moreover, what is meant by hazardous waste and public health in the context of this book? This chapter addresses these questions and introduces CERCLA and RCRA, the two key federal statutes on waste management.

Industrial development and modern agricultural practices have both contributed mightily to human advancement and well-being. The former serves as the engine for modern national economies; the latter is essential for producing food and fibers. It can be argued that advances in industrialization and agriculture have improved the quality of life, including the public’s health. For instance, post-World War II industrialization in the United States produced the pharmaceutical industry, which, in turn, has produced an abundance of drugs essential for treatment or prevention of human disease. Moreover, industrialization has led to development and production of consumer products that make work easier and safer. Similarly, agricultural improvements have increased food production in many parts of the world, with obvious benefits for human health.

However, both industrial development and modern agriculture have undeniably harmed environmental quality and ecosystem integrity. One significant adverse effect is the generation of waste. Waste is defined as a by-product that is deemed useless or worthless by the discarer. By this definition, chemicals discarded into the environment are a form of waste. Some effects of environmental contaminants on human health and ecosystems are relatively well understood; others are still being investigated and debated. For example, the association between vehicle exhaust and ambient air pollution is well-known, including the deleterious release of lead from leaded gasoline into the environment and its effect on human health as lead accumulates in the body. Less well understood is how chlorofluorocarbons contribute to the reduction of ozone in the atmosphere, leading ultimately to a predicted increase in the incidence of skin cancer (NRC, 1991a; Rom, 1992).

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1 Lead is banned as a gasoline additive in the United States but not in some other countries.
Some agricultural practices have also contributed to environmental degradation and damage to ecologic systems. For example, excessive reliance on chemical fertilizers increased levels of chemical contaminants in groundwater and surface water in some areas of the United States. Another example is the effects on ecologic systems of DDT from past agricultural, consumer, and public health uses (e.g., mosquito control). DDT reduced the numbers of some wild birds through eggshell thinning. A contemporary controversy concerns the effects on the global environment as rain forests are destroyed for conversion into cropland. These examples, and others that could be cited, show that agricultural practices, if not adequately evaluated for their ecologic effects, can seriously damage the environment and ecologic systems.

Modern industrial societies produce a multitude of products intended for consumption. Indeed, consumerism fostered by free enterprise undergirds national economies in many countries. The production and distribution of consumer goods has brought many benefits to individual consumers; for example, products such as video equipment used for education and entertainment can improve the quality of life. But these positive contributions have come with some deleterious effects. One such effect is the environmental impact of increased waste generation. Discarded consumer products soon become waste that requires disposal. In 1988, each person in the United States produced about four to five pounds of waste per day (PHS, 1990; Plotzman, 1992). Household waste adds to the municipal waste stream. More than 50,000 tons of waste are produced each day in Los Angeles County, California. Figures available for several industrial countries show a pattern similar to that in the United States—large amounts of waste produced per person per year (Plotzman, 1992).

Studies conducted by the University of Arizona have produced a comprehensive database on residential waste. Detailed characterization of household hazardous waste showed that 11 million hazardous waste items were generated by the approximately 120,000 households in Tucson, Arizona (Wilson and Rathje, 1989). They also collected curbside household waste in Tucson and Phoenix, Arizona; New Orleans, Louisiana; and Marin County, California. The household hazardous waste fraction ranged between 0.42 and 0.61% of the refuse weight. The investigators noted that residential waste sent to landfills may contain higher concentrations of hazardous materials than does commercial waste.

The kinds of hazardous materials discarded in household waste and the householders' knowledge about hazardous waste management were studied in two counties in Arizona (Wolf et al., 1997). Telephone and face-to-face interviews with residents about their hazardous waste practices were conducted in Pima and Maricopa counties, Arizona. The results indicated residents were improperly disposing of significant amounts of household hazardous waste. Of note was that although Pima County had a household hazardous waste program and public awareness support, only 5% of the population participated. The investigators grouped hazardous materials in household waste for 1995-1996 into five categories, shown in Figure 1.1. The category automotive includes batteries and antifreeze. Two categories, automobile and paint/paint products, represented more than 80% of household hazardous waste. The investigators concluded that household hazardous waste programs must be supplemented by strong educational programs, including how the waste can cause adverse effects on human health and the environment.

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Improper disposal of common household waste can cause health problems by, for example, creating noxious smoke from burning trash or providing breeding grounds for vermin. In addition, hazardous substances in municipal waste released from landfills or other methods of waste disposal can contribute to air, water, and food-chain pollution. Releases of hazardous substances from hazardous waste sites into groundwater can significantly threaten drinking water supplies. To reduce the amount of household waste produced per household will require greater efforts in recycling, biodegradable packaging for consumer products, and changes in personal lifestyles.

Modern economies are built on both industrialization and agriculture, with benefits that accrue from both. But environmental degradation, with consequent implications for human health and ecologic systems, has accompanied this development. In some sense, the old cliche “Haste makes waste” applies here. Hazardous waste left expediently in the environment because it was often inexpensive to do so has now become a major concern. What is the basis for this concern and what does it mean for human health and its impact on ecologic systems? Some background about the two major U.S. statutes on hazardous waste management will be helpful.

CERCLA AND RCRA

In the 1970s, discoveries of toxic substances in communities at Love Canal, New York and the “Valley of the Drums” in Kentucky, and a chemical plant fire in Elizabeth City, New Jersey, among others, riveted the attention of the U.S. public and galvanized legislative action. Hazardous waste and its presence in residential environments became a concern of environmentalists, legislators, and public health officials alike. The legislative outcome was the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), quickly christened the Superfund Act, after the multibillion-dollar Hazardous Substance Superfund created by the act.

The Hazardous Substance Superfund is a trust fund held by the U.S. Treasury and funded by taxes on select parts of private industry: petroleum excise taxes, a chemical

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3 The Hazardous Substance Superfund was authorized by CERCLA, section 9507. In 1995, Congress allowed the authority to impose the Hazardous Substances Superfund tax to expire. CERCLA programs have been financed after 1995 on unexpended funds in the Superfund.
feedstock tax, a corporate environmental tax, general revenues, and other sources (Probst, 1992). Ultimate responsibility for the fund rests with the U.S. Congress. Appropriations from the trust fund are made annually to the U.S. Environmental Protection Agency (EPA) for administration. This budget appropriation to the EPA funds CERCLA's directives of identifying uncontrolled hazardous waste sites and sites where emergency spills have occurred, protecting the public's health and environmental media from the effects of releases from identified sites, and remediating (i.e., cleaning up) those sites that merit such action. That same budget appropriation to the EPA contains funds for CERCLA mandates to the Agency for Toxic Substances and Disease Registry (ATSDR) and a program of basic research and worker training for site remediation workers administered by the National Institute of Environmental Health Sciences.

The word Superfund is sometimes used to refer to both the CERCLA statute and the Hazardous Substance Superfund. However, in the context of this book, CERCLA will be used exclusively to describe the statute and programs of the same name.

The CERCLA statute of 1980 contains what is called a "sunset clause," which is a legislative device that sets a time limit on a specific law. The sun sets on the statute after a prescribed passage of time, unless Congress continues the law through reauthorization. For CERCLA, this time limit is five years. Reauthorization means that Congress takes action to extend a law's authorities and mandates. This process usually involves congressional hearings, debate, and ultimately, a vote to extend or terminate the law under consideration. In 1986, Congress reauthorized CERCLA, but with substantive changes through various amendments to the 1980 statute. In 1991, Congress voted simply to extend CERCLA, as amended in 1986, for another five years. As of this writing, CERCLA has not been reauthorized again, but the EPA has made several changes in how it administers various parts of the statute.

At the heart of CERCLA is the philosophy, evidenced by enforcement powers given to the EPA, to hold accountable those parties responsible for the consequences of hazardous substances released into the environment from uncontrolled hazardous waste sites. As noted in the Preface, CERCLA is a federal environmental law without parallel in its controversy. Much of the controversy derives from the "polluter pays" philosophy, because parties can be held liable for costs they may deem inappropriate or excessive.

Opinion is widely divided on CERCLA's importance for protecting human health and remediating environmental contamination. Because CERCLA was enacted by Congress primarily from concern that substances released from uncontrolled waste sites were causing cancer and other dire health problems, some of the controversy attending CERCLA gets voiced as issues of human health. The 1986 congressional debate over CERCLA's reauthorization illustrates the polar extremes of view on issues of health:

On this point we should be absolutely clear. Uncontrolled releases of hazardous substances present a very real threat to the public health. Superfund is the way to clean up the contaminated water and soil so that our children do not become ill from toxic chemicals (Senator George Mitchell, 1986).

It is time to move faster, to rid our environment of the toxics that are poisoning our land and water, and threatening our citizens (Senator Frank Lautenberg, 1985).

As a matter of fact, at this moment I honestly do not know if there are any victims of diseases caused by exposure to releases from Superfund sites (Senator James Abdnor, 1985).
The opinions quoted probably reflect similar polar differences of view between segments of private industry and environmental organizations about hazardous waste as an environmental health problem. (Environmental health is used here to denote the area of public health that is concerned with effects on human health of socioeconomic conditions and physical factors in the environment.) These differences will narrow as scientific information and experience accrue. It is hoped that the information in this book will contribute to a better base of technical information on the costs and benefits of the CERCLA statute.

Distinct from CERCLA, which covers uncontrolled hazardous waste sites, is the Resource Conservation and Recovery Act (RCRA), which pertains to the permitted, controlled management of hazardous and solid wastes. RCRA is the federal statute that regulates waste generators, waste transporters, and waste management facilities. RCRA began as an amendment to the Solid Waste Disposal Act in 1965, was enacted into law in 1976, and was amended in 1980 and 1984. Sites covered by RCRA include landfills, waste piles, surface impoundments, land treatment units, tanks, containment areas, and satellite accumulation areas (Ruttenberg et al., 1996). The EPA is the leading federal agency administering the terms of RCRA under four broad programs: hazardous solid waste, nonhazardous solid waste, medical waste, and underground storage.

Remediation of RCRA sites is handled differently from that of CERCLA sites. No funding source like the Hazardous Substance Superfund is available for RCRA sites requiring remediation (Ruttenberg et al., 1996). Instead, corrective actions issued by the EPA under RCRA are funded by site owners or operators. Such actions can involve site cleanups. Releases from solid waste management units (SWMUs) at treatment, storage, and disposal facilities also are covered by the RCRA corrective action program.

PUBLIC PERCEPTION OF HAZARDOUS WASTE

According to opinion polls, the American public continues to place a high priority on the need to reduce hazardous waste and to repair existing environmental damage. This concern has mobilized many community groups and national environmental organizations to oppose the generation, transportation, and disposal of hazardous waste. This opposition has given rise to the term NIMBY, which stands for Not In My BackYard. Community groups, in particular, often express NIMBY concerns through local opposition to the placement of landfills, incinerators, and other forms of waste storage or destruction facilities within their locales. An example is the vocal opposition of communities to construction of incinerators because of concern that dioxins will be released as incinerator emissions.

NIMBY actions are usually rooted in concerns about human health effects of hazardous waste and economic consequences to homeowners (such as reduced property values), although NIMBY actions also are being based on environmental inequity (Chapter 9). According to Szasz (1994), local community groups gradually enlarge their sphere of contact beyond local agencies and officials and engage national grassroots organizations. The result is a broadening of environmental awareness and involvement. This kind of grassroots networking is a consequential political force that has had significant impact on local and federal government policies on waste reduction, recycling, waste site cleanups, and waste management policies.

In 1996 the Superfund Reform Coalition, an alliance of business organizations interested in reforming CERCLA, surveyed public opinion of the major federal environmen-
tal laws and priorities (Silverman, 1996). More than 1,000 registered voters between the ages of 18 and 65 from the two major U.S. political parties were surveyed. Although nearly 60% of those surveyed expressed support for less government regulation in general, the results changed with respect to environmental regulation. According to the survey, 36% of respondents indicated there was not enough environmental regulation; 21% said there was too much; and 21% indicated the amount of environmental regulation was about right.

The Coalition's survey found hazardous waste cleanup and safe disposal of hazardous waste were top priorities for 27% of respondents, a figure that exceeded priorities for air and water pollution. When surveyors presented the respondents with "historical data on the performance of Superfund," 49% of respondents said the program had been unsuccessful and needed an immediate overhaul (Silverman, 1996). The extent of the public's dissatisfaction with Superfund cannot be ascertained from this survey because of possible biasing due to how the surveyors presented the Superfund program's performance data to respondents.

The Coalition's survey and results of other public opinion polls show the public is highly concerned about hazardous waste hazards but also believes the CERCLA statute and its implementation need improvement. The high priority ascribed by the public is at odds with the priority given by scientific experts. Chapter 8 discusses how the public perceives risk, and Chapter 10 describes the results of comparative risk assessments of environmental hazards, including hazardous waste.

DEFINITIONS OF HAZARDOUS WASTE AND HAZARDOUS SUBSTANCES

Before proceeding further, hazardous waste and hazardous substance must be defined. In a general sense, hazardous waste is, as the name implies, discarded material that has the potential to do harm. However, laws and international directives on hazardous waste require more precise definitions.

As defined in RCRA, "Hazardous waste means a solid waste, or combination of solid wastes, that because of its quantity, concentration, or physical, chemical, or infectious characteristics, may (A) cause or significantly contribute to an increase in mortality or an increase in serious, irreversible, or incapacitating reversible illness; or (B) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed" (ELI, 1989).

The European Community (EC) has taken a more operational approach to defining hazardous waste (ELI, 1992). By their definition, hazardous waste means wastes that have one or more of the following 15 properties: explosive, oxidizing, highly flammable, flammable, irritant, harmful, toxic, carcinogenic, corrosive, infectious, teratogenic, mutagenic, ecotoxic; substances and preparations that release toxic or very toxic gases in contact with water, air, or an acid; substances and preparations capable by any means, after disposal, of yielding another substance, for example, a leachate, that possesses any of the other 14 properties. Using these criteria, lists of hazardous wastes are developed by the EC and used for administrative purposes such as regulating transport and disposal of individual hazardous wastes.

4 The European Community is now called the European Union.
The term *hazardous substance* is defined by CERCLA in operational terms as any substance designated by CERCLA itself and other federal statutes. At its root, *hazardous substance* is a legal term but in application refers to a specific pollutant or contaminant. CERCLA defines *pollutant or contaminant* to "...include, but not be limited to, any element, substance, compound, or mixture, including disease-causing agents, which after release into the environment and upon exposure, ingestion, inhalation, or assimilation into any organism, either directly from the environment or indirectly by ingestion through food chains, will or may reasonably be anticipated to cause death, disease, behavioral abnormalities, cancer, genetic mutation, physiologic malfunctions (including malfunctions in reproduction) or physical deformations, in such organisms or their offspring; except that the term 'pollutant or contaminant' shall not include petroleum ...and shall not include natural gas, liquefied natural gas, or synthetic gas..." (ELI, 1989). This definition was obviously written by attorneys, for attorneys!

*Hazardous waste* and *hazardous substance* will be used in this book to denote waste and substances which possess properties that can cause harm to human health and ecologic systems. However, the reader is advised that these terms take on specific meanings under various legal and regulatory acts, such as CERCLA. Also included as hazardous waste for the purposes of this book are substances released during chemical spills and similar uncontrolled releases of hazardous substances into the environment.

**EXTENT OF THE HAZARDOUS WASTE PROBLEM**

Industrialized countries produce huge quantities of hazardous waste. This often results from inefficient or uneconomical production methods and use of energy and materials. In the United States, the "solution" frequently chosen in the past was to dispose of the waste in landfills or waterways (rivers, lakes), or to incinerate it. The end result is a toxic legacy in the environment. Too often an attitude of "The solution to pollution is dilution" has prevailed. That practice doesn't work, especially for pollutants that are persistent in the environment and that accumulate in ecologic systems. An attitude of "The solution to pollution is diminution" should characterize current and future waste management practices. From the perspective of human health and ecologic systems, prevention of environmental degradation leads to prevention of adverse health effects because exposure to toxicants does not occur. In public health parlance, this is primary prevention at work; that is, elimination of the hazard.

The exact volume of hazardous waste produced globally is unknown. International comparisons are almost impossible because of differences in definition and classification of hazardous wastes from country to country. Batstone et al. (1989) estimate that, for several western European countries, hazardous waste production is about 5,000 tons per billion U.S. dollars of gross domestic products (GDP). On this basis, the United States is estimated to produce 75,000 tons per annum (tpa); and Canada, 10,000 tpa. Waste production per GDP was estimated to be 10,000 tons in the former Soviet Union; that in other countries with mature industry, 5,000 tons; in newly industrialized countries, 2,000 tons; and in developing countries, 1,000 tons.

Other estimates of the annual generation of hazardous waste in the United States were developed by the Office of Technology Assessment (OTA), the Congressional Budget Office (CBO), and the EPA. The OTA estimates that 255–275 million tonnes\(^5\) of

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\(^5\) 1 tonne = 1,000 kilograms.
hazardous waste are produced (OTA, 1983). The EPA estimated in 1991 that 275 million tons of hazardous waste was produced (Skinner, 1991). Moreover, the EPA cites estimates from the Congressional Budget Office (CBO) on the major generators of hazardous waste, showing that chemical and allied products account for about half of all hazardous waste generated (Figure 1.2).

By whatever yardstick, the quantities of hazardous wastes generated each year are enormous, and without proper management of its storage or disposal, have the potential for compromising the public's health and the well-being of ecosystems.

**Number of CERCLA Hazardous Waste Sites**

Hazardous waste has often been discarded into the environment in landfills and on industrial properties. In turn, these properties have themselves been discarded. At the end of December 1996, the EPA's inventory of uncontrolled hazardous waste sites, called the Comprehensive Environmental Response and Liability Information System, listed 41,266 sites (EPA, 1996a). However, in 1995 the EPA archived approximately 30,000 of these sites because they posed little or no threat to health or the environment; no further federal remedial action is planned for them (Brown, 1997). As of December 31, 1996, 1,296 sites were listed on or proposed for the EPA's National Priorities List (NPL), which are the sites posing the greatest threat to the public's health and the environment (EPA, 1996b,c). NPL sites also become the subject of federal funding and enforcement efforts. More specifically, NPL sites are identified by the EPA for remediation, using CERCLA authorities for recovering remediation costs from potentially responsible parties (PRPs).

Uncontrolled hazardous waste sites associated with U.S. federal government facilities are of particular importance because of their potentially high remediation costs. These facilities include sites operated by the Department of Defense (DOD, military bases) and the Department of Energy (DOE, weapons complexes). According to the National Research Council, 17,482 contaminated sites were located at 1,855 DOD installations as of September 1990 and 3,700 sites at 500 DOE facilities (NRC, 1994). Some DOE sites cover large geographic areas and are toxicologically very complex in terms of both the radioactive and chemical wastes released into the environment.

As of April 1995, federal agencies had placed 2,070 facilities on the federal facility docket, the EPA's listing of the facilities awaiting evaluation for possible cleanup (GAO, 1996). The EPA has placed 154 federal facilities on the NPL, and, as of February 1996, had proposed another five facilities for NPL listing (GAO, 1996). Of the 154 federal facilities on the NPL, the largest number are DOD facilities (127), followed by the Departments of Energy (20), Interior (2), Agriculture (2), Transportation (1), and other departments (2).

**Other Hazardous Waste Sites**

Remedial actions are needed at other hazardous waste sites in addition to CERCLA sites. These include RCRA sites and those under the control of states and private parties. According to Ruttenberg et al. (1996), the number of treatment, storage, and disposal facilities covered under RCRA is in the range of 4,700–5,100, with 1,500–3,500 requiring some kind of corrective action (Ruttenberg et al., 1996). Corrective actions were under way or completed at 247 facilities, about 3,500 facilities had undergone RCRA facility
assessments, and 614 were undergoing RCRA facilities investigations. Of these RCRA sites, about half use off-site disposal remedies and half use innovative treatment technologies.

Furthermore, there are an estimated 21,575 large-quantity waste generators; 190,431 small-quantity waste generators; and 2,389 treatment, storage, and disposal facilities acting as waste generators are in existence (Ruttenberg et al., 1996). The corrective actions and remediation efforts at these sites are unknown.

In addition to the federal Superfund program, states and U.S. territories administer major programs of removal and remedial actions at non-NPL sites that parallel those of the federal CERCLA. The U.S. Office of Technology Assessment (OTA) estimated that as many as 439,000 state sites might need to be evaluated for remediation (OTA, 1989). According to the Association of State and Territorial Solid Waste Management Officials (ASTSWMO), which acquired data from 39 states and one territory, as of December 31, 1992, 21,905 hazardous waste sites had been identified (ASTSWMO, 1994).

Anecdotal information indicates that many hazardous waste sites have been voluntarily remediated by private parties. However, no source is available to the public for keeping track of the number of sites voluntarily remediated, the method of remediation, the costs, or other pertinent data. The numbers of such sites and the effects of the remediation are therefore unknown.

Costs of Uncontrolled Hazardous Waste Sites

In 1991, the EPA estimated that cleaning up the nonfederal NPL sites could cost more than $30 billion. Reisch et al. (1996) estimated the average cost for cleaning up nonfederal sites is approximately $30 million; the EPA (1998a) estimates a figure of $18–20 million. In addition to NPL sites, the EPA estimated that about 4,000 facilities, representing 64,000 solid waste management units covered under RCRA, may require cleanup, but no cost estimates were provided (Habicht, 1991).

Russell et al. (1991) projected that cumulative cleanup costs for all sites from the year 1990 through 2020, using current remediation practices, will be approximately $750 billion, with a plausible lower bound at something less than $500 billion and an upper bound at approximately $1 trillion. Their analysis included both federal and nonfederal sites and covered CERCLA NPL sites, state and private-sector waste remediation pro-
grams, underground storage tanks, and RCRA sites requiring corrective action. Specific to CERCLA NPL sites, Russell et al. estimate cumulative costs through year 2020 to range from $106 billion (assuming 2,100 nonfederal sites) to $302 billion (assuming 6,000 nonfederal sites). Less stringent cleanup would, of course, lower these projected costs; greater stringency would increase them. Their "best guess" of cumulative remediation costs for federal facilities is $240 billion for DOE sites and $30 billion for DOD sites.

The Federal Facilities Policy Group (FFPG) conducted an analysis in 1995 of costs to remediate federal sites. The group was convened by the White House's Office of Management and Budget and the Council on Environmental Quality to review the current status and future course of environmental response and restoration of federal facilities. In the course of the review, estimates were derived of the numbers and costs of federal facilities and sites contaminated with hazardous substances. These estimates are listed in Table 1.1, which profiles the federal departments with the largest number of contaminated sites. Included are DOE, DOD, Department of Interior (DOI), Department of Agriculture (USDA), and the National Aeronautics and Space Administration (NASA).

The federal departments identified in Table 1.1 have the greatest number of facilities and contaminated sites that require remediation. Cleanup costs are given in 1994 dollars. The DOI has the largest number of active sites requiring review and potential remediation. The DOE, because of the complex nature of their facilities and contaminated sites, represents the single largest cost for site remediation. According to the Federal Facilities Policy Group (FFPG), site remediation and attendant costs for DOE, DOD, and NASA will come from federal funds, that is, from the federal treasury. Sites that are the responsibility of the DOI and the USDA will derive their cleanup costs from a mix of federal, private party, and local government funds (FFPG, 1995). The FFPG estimates the total cost to remediate federal sites at approximately $400 billion in 1994 dollars.

The CBO (1994) released in 1994 a set of cost estimates for nonfederal sites, analyzing three scenarios for CERCLA costs after 1992. The CBO's estimates were based on assumptions related to the number of nonfederal NPL sites. The base-case estimate (4,000 nonfederal NPL sites) is $74 billion in discounted, present-worth dollars; the low-case estimate (2,300 sites) is $42 billion; and the high-case estimate (7,000 sites) is $120 billion. Annual undiscounted costs in the base-case peak are $9.1 billion in the year 2003; they average $2.9 billion per year through the year 2070 (CBO, 1994).

The CBO's estimates of future CERCLA costs are different from earlier estimates developed by the EPA (Habicht, 1991) and Russell et al. (1991). The main factors that explain the differences are CBO's broader coverage of costs and use of discounted dollars, different average cleanup costs per site, and different numbers of sites on the NPL. Specifically, the CBO figure includes all future public and private CERCLA expenditures; the Russell et al. estimates cover public and private costs for study and cleanup at NPL sites, but omit administrative and legal expenses and the costs of screening and removals at non-NPL sites. Furthermore, the CBO (1994) estimate is in present-worth dollars; Russell et al.'s (1991) figures are expressed in undiscounted dollars.

In addition to the costs of site remediation, other site-specific costs add to the overall burden of protecting the public and ecologic systems against the legacy of uncontrolled releases of hazardous substances. In particular, operations and maintenance (O&M) activities will be necessary at many sites. These activities are meant to ensure that the remedy implemented at a site continues to operate effectively. The GAO reviewed information from 275 NPL sites where the cleanup remedy had been implemented. Of
Table 1.1. Profile of Key Federal Departments' Facilities and Sites (FFPG, 1995).

<table>
<thead>
<tr>
<th>Nature of contamination</th>
<th>DOE</th>
<th>DOD</th>
<th>DOI</th>
<th>USDA</th>
<th>NASA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radioactive, hazardous, and mixed waste and fissile material</td>
<td>10,000 sites (former weapons-production facilities)</td>
<td>21,425 sites (underground tanks, landfills, spill areas, storage areas)</td>
<td>26,000 sites (abandoned mines, oil &amp; gas production, landfills)</td>
<td>3,000 sites (abandoned mines, landfills)</td>
<td>730 sites (underground storage tanks, spill areas)</td>
</tr>
<tr>
<td>Number of potentially contaminated sites (and site types)</td>
<td>137</td>
<td>1,769</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>17</td>
</tr>
<tr>
<td>Number of potentially contaminated facilities</td>
<td>10,000</td>
<td>11,785</td>
<td>26,000</td>
<td>3,000</td>
<td>575</td>
</tr>
<tr>
<td>Number of active sites</td>
<td>$200–$350 billion</td>
<td>$26.2 billion</td>
<td>$3.9–$8.2 billion</td>
<td>$2.5 billion</td>
<td>$1.5–$2 billion</td>
</tr>
<tr>
<td>Current estimate to complete cleanup</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
this number, 173 sites were found to require O&M activities by the federal government, states, and parties responsible for cleanup costs.

In addition to the federal CERCLA program, states and U.S. territories have major programs under way for removal and remedial actions at non-NPL sites. According to ASTSWMO (1994), 3,527 sites had at least one completed state removal, 4,834 sites were in a state's version of the remedial investigation/feasibility study phase, 2,689 sites have completed construction through state remedial processes, and 11,000 sites were described as still active in some part of their state remedial process. The costs associated with 3,395 sites amounted to approximately $1.2 billion. This program represents a substantial commitment on the part of states and territories to removing toxic wastes from the environment.

The costs of O&M activities vary according to the kind of remediation used at a site. For example, the GAO found that when the remedial action uses a technology to contain surface waste, the ensuing O&M activities that follow the containment system construction could typically cost $5 million per site over 30 years. When the cleanup remedy included treating contaminated groundwater, O&M activities could cost $17 million per site over 30 years. The GAO concluded, "For clean-up remedies that EPA or the responsible parties have already undertaken or will undertake from now to fiscal year 2005, we estimate that about $32 billion will be needed for operations and maintenance costs nationwide through fiscal year 2040" (GAO, 1995a). Of this amount, $18 billion would come from private sector parties, $8 billion from states, and $5 billion would be paid by the federal government.

By any measure, the cost in money and human resources to remediate the legacy of hazardous wastes left in the American environment will be huge if current policies on site identification, prioritization, and remediation are maintained. Because of the extensive resources committed to remediating hazardous waste sites and related environmental hazards, knowing the magnitude of the human health hazard is important to permit balancing costs and benefits. This book is intended to provide data relevant to the cost/benefit calculus.

**Numbers of Sites Remediated**

The ultimate environmental impact of the CERCLA statute is the remediation of uncontrolled hazardous waste sites. This action removes environmental contamination that can potentially cause adverse human health and ecologic effects. The actual cleanup of a site is the culmination of the Superfund remediation process. Remedial actions at a particular site may take years, depending on such factors as size of the site and the specific cleanup methods chosen. After remediation, NPL sites are removed from the NPL. According to the EPA, cleanup construction has been completed at 504 NPL sites and another 473 sites are in construction, as of January 1998. Moreover, the EPA states that more than 89% of nonfederal NPL sites are either undergoing cleanup construction (remedial or removal), or have been completed (Fields, 1998).

One criticism of the CERCLA program is the allegedly slow pace of NPL site remediation. The U.S. Department of Justice (DOJ, 1996) asserts that the rate of site remediation has quickened because of reforms in the EPA's administration of CERCLA. However, the GAO (1997) found that the time to complete remediation at NPL sites has increased over time (Figure 1.3). From 1986 to 1989, cleanup projects were completed, on average, in 3.9 years after sites had been placed on the NPL. By 1996, the time for
Cleanup completions had increased to an average of 10.6 years. According to the GAO, the EPA attributed the increase to the growing complexity of sites, efforts to reach settlements with parties potentially responsible for the costs of site remediation, and resource constraints.

The data in Figure 1.3, which imply that the time to complete cleanups of NPL sites may continue to increase, have been challenged by the EPA (Fields, 1998). The EPA contends that the GAO analysis failed to acknowledge a backlog of hundreds of sites already in existence when CERCLA was enacted, and relied on analysis of operable units, not site completions. There is merit to the EPA's complaint about the GAO analysis; administrative reforms in how the EPA administers its CERCLA programs should decrease the time-to-cleanup for NPL sites.

States and territories have remediated non-NPL sites more quickly than the EPA has remediated CERCLA sites. Of 6,052 such remediated sites, 4,261 were completed in less than one year (ASTSWMO, 1994). This duration is less than for federal CERCLA sites, but the comparison is complicated. CERCLA defines duration of response actions as the time from the discovery of a site through the remedial action, whereas state/territories define it as the time from the start of the remedial investigation through the remedial action (ibid.). Moreover, it can be argued that the federal CERCLA program, which includes federal facilities, remediates sites that are more contaminated and complicated than are the state/territorial sites.

Given the high cost of remediating hazardous waste sites and the nature of assigning costs to PRPs, it is not surprising to find that remedy selection by the EPA and individual companies (where voluntary cleanup is undertaken) is a source of conflict. A GAO study found several alleged problems with the completeness and consistency of cleanup decisions at sites managed by both the EPA and PRPs. Problems noted were inadequate cleanup goals and insufficient justification for selecting a particular remedial action (GAO, 1992). The EPA's administrative reforms in implementing CERCLA programs have
made improvements in several areas, but remedy selection and cleanup goals will remain subjects of active debate as the Superfund program matures. This stems from CERCLA's financial implications for parties responsible for cleanup and other costs.

**Number of Persons Who Live Near NPL Sites**

The number of persons in the United States at potential health risk from releases of hazardous substances from waste sites is difficult to estimate with any precision, given uncertainties in the frequency and geographic extent of releases. However, using currently available data, two estimates exist of numbers of persons at potential risk. Using data from 1,134 NPL sites in 1991, the EPA estimated that approximately 41 million persons live within four-mile radii of the sites, and an average of 3,325 persons live within one-mile radii of such sites (NRC, 1991b). This means that one of six Americans lives within four miles of an NPL site. In 1995, the EPA administrator raised this estimate in congressional testimony: "With approximately 73 million persons living fewer than four miles from one or more of the nation's active Superfund sites, they present some of the most complex and diverse of all health and environmental pollution problems facing us today" (Browner, 1995). The derivation of this new estimate was not stated.

A demographic analysis of persons living near 1,200 NPL sites led ATSDR to estimate that approximately 11 million persons live within one-mile borders of those sites (Heitgerd et al., 1995). A separate analysis by ATSDR of 972 NPL sites found 949,000 children six years or younger lived within one mile of sites' borders, which represented 11% of the population. This is an average of 980 children six years or younger per NPL site. Given a current total of about 1,300 NPL sites, one can calculate that approximately 1.3 million young children live within one mile borders of NPL sites. This is a large number of young children at potential health risk. Actual health risk must be determined by such factors as patterns of release of substances from sites, degree of exposure of persons in contact with released substances, toxicity of the substances, and individual susceptibility to a substance's toxicity.

**CHARACTERISTICS OF UNCONTROLLED WASTE SITES**

As the number of NPL sites and the cost to remediate them have increased, interest has developed in characterizing the sites on the basis of demographics and socioeconomic features, influenced in part by environmental equity concerns, that is, concern that hazardous waste sites may be distributed inequitably in minority and low-income communities (Chapter 9). Statistical characterization of NPL sites is therefore important for both social and economic reasons. Zimmerman examined the socioeconomic characteristics of 1,090 NPL sites, which was approximately the number of NPL sites at the time of his study (1993). He examined approximately 800 in depth. Several of his findings are useful for placing NPL sites in perspective:

- Population. The populations living near NPL sites varied widely. The mean population in 1990 was about 88,000, and the standard deviation was about 278,000.

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6 Demography focuses on population trends such as growth; for example, increases in percentage of the elderly in the U.S. population, and migration patterns (Detels and Breslow, 1991).
• Age. An average of 13% of the populations in communities with NPL sites in 1990 were elderly, comparable with the 12.4% of elderly in the nation.

• Population growth. NPL sites in 1990 were mostly located in communities that had modest growth rates of about 5% between 1986 and 1990. The national growth rate for the same period was 3.8%.

• Population density. NPL sites in 1990 were located in rather densely populated areas. The 1990 mean density of 2,658 persons per square mile is several times greater than the 1990 national average of 70.3 persons per square mile. Zimmerman notes that this large population density is an artifact of the NPL designation process (i.e., EPA's Hazard Ranking System), which uses population density as a criterion for listing a site on the NPL.

• House value. The median house value was $75,000 in communities with NPL sites in 1990, with a high degree of variability. This was about equal to the national median house value of $79,100 in 1990.

• Home ownership. Owner occupancy in communities with NPL sites in 1990 averaged about 60%, compared with the national average of 64 percent.

Zimmerman's data suggest that some key socioeconomic indicators for communities near NPL sites in 1990; that is, population density, house values, and home ownership, did not differ from corresponding national data. A key difference, however, was the finding that NPL sites were located in densely populated areas, which are given priority by the EPA's Hazard Ranking System.

**Municipal Solid Waste Landfills**

Because municipal solid waste landfills are known to receive some hazardous materials from households and industry, the GAO sought survey responses from 301 metropolitan and 322 nonmetropolitan landfills concerning various solid waste issues (GAO, 1995c). Their survey, like the Zimmerman examination of socioeconomic characteristics of populations living near uncontrolled hazardous waste sites, found several interesting characteristics of solid waste landfills of relevance to human health issues.

• Counties and municipal governments owned 69% of metropolitan landfills and 79% of nonmetropolitan landfills in operation in 1992.

• The average metropolitan landfill was about 191 acres in size, with a range of 1–2,000 acres. The average nonmetropolitan landfill was about 98 acres, with a range of 1–1,200 acres.

• The average metropolitan landfill received about 50% of its waste from the community where it was located and 36% from the remainder of the county. Comparable percentages for nonmetropolitan landfills were 61% and 34%, respectively.

• Typically, the waste sent to landfills was household waste, industrial nonhazardous waste, and construction-related debris.

• GAO estimated 7% of the metropolitan landfills had received hazardous waste from sources that generate small quantities of waste and less than 3% had received hazardous waste from sources that generate large quantities of waste. Among nonmetropolitan landfills, 8% had received hazardous waste from small-quantity generators, and 1% received from large-quantity generators.

• No protective liners were beneath any of the waste units for 47% of metropolitan landfills; 55% did not have leachate collection systems in place at any of their waste units. More than 90% reported that they had groundwater monitoring. About 16% of metropolitan landfills had caused groundwater contamination at some time.
• No protective liners were beneath any of the waste units for 66% of nonmetropolitan landfills; 80% did not have leachate collection systems in place; 67% reported they had groundwater monitoring in place. About 7% of nonmetropolitan landfills were reported as having caused groundwater contamination at some time.

The GAO survey (1995c) and the study of Wolf et al. (1997) indicate that small amounts of hazardous materials do reach metropolitan and nonmetropolitan landfills. The volume of these materials is not well characterized, but their presence in landfills justifies a human health concern.

SYNTHESIS

Public opinion polls indicate that the American public continues to place a high priority on the need to reduce hazardous waste and to repair existing environmental damage. An industry coalition's survey found hazardous waste cleanup and safe disposal of hazardous waste were top priorities for 27% of respondents, a figure that exceeded priorities ascribed by the survey's respondents for air and water pollution. Survey respondents also indicated that the CERCLA program had been unsuccessful and needs fundamental overhaul.

In the 1970s, discoveries of hazardous substances in communities became a concern to environmentalists, legislators, and public health officials alike. The legislative outcome was the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), which governs actions to remediate uncontrolled hazardous waste sites and responds to human health impacts.

In distinction to CERCLA, the Resource Conservation and Recovery Act (RCRA) covers the permitted, controlled management of hazardous and solid wastes. RCRA is the federal statute that regulates waste generators, waste transporters, and waste management facilities. Sites covered by RCRA include landfills, waste piles, surface impoundments, land treatment units, tanks, containment areas, and satellite accumulation areas (Ruttenberg et al., 1996).

The number of hazardous waste sites is large. At the end of December 1996, the EPA's inventory listed 41,266 uncontrolled hazardous waste sites (EPA, 1996a). However, the EPA has inactivated approximately 30,000 sites because they posed little or no threat to health or the environment (Browner, 1997). As of December 31, 1996, 1,296 sites were listed on or proposed for the EPA's National Priorities List (NPL), which are the sites posing the greatest threat to the public's health and the environment (EPA, 1996b,c).

Of particular import are uncontrolled waste sites that are the responsibility of the federal government. As of April 1995, federal agencies had placed 2,070 facilities on the federal facility docket, the EPA's listing of the facilities awaiting evaluation for possible cleanup (GAO, 1996). The EPA has placed 154 federal facilities on the NPL and, as of February 1996, had proposed another five facilities for NPL listing (GAO, 1996). Of the 154 federal facilities on the NPL, the largest number are DOD facilities (127), followed by the Departments of Energy (20), Interior (2), Agriculture (2), Transportation (1), and other departments (2).

In addition to the federal Superfund program, states and U.S. territories have major programs under way for removal and remedial actions at non-NPL sites that parallel those of the federal CERCLA. The GAO estimates 130,000 to 425,000 state sites might need to be evaluated for possible remediation. As of December 31, 1992, according to
data from 39 states and one territory, 21,905 hazardous waste sites had been identified. Of these, 3,527 sites had undergone at least one completed state removal, 4,834 sites were in a state's version of the remedial investigation/feasibility study phase, 2,689 sites had completed construction through state remedial processes, and 11,000 sites were described as still active in some part of their state remedial process (ASTSWMO, 1994). The costs associated with 3,395 sites amounted to approximately $1.2 billion.

The cost of remediating hazardous waste sites and the impact on human health and natural resources is huge. Russell et al. (1991) projected that cumulative cleanup costs for all sites from the year 1990 through 2020, using current remediation practices, will be approximately $750 billion, with plausible lower bound at something less than $500 billion and upper bound at approximately $1 trillion (Russell et al., 1991). Their analysis included both federal and nonfederal sites and covered CERCLA NPL sites, state and private sector waste remediation programs, underground storage tanks, and RCRA sites requiring corrective action. Specific to CERCLA NPL sites, Russell et al. estimate cumulative costs through year 2020 to range from $106 billion (assuming 2,100 nonfederal sites) to $302 billion (assuming 6,000 nonfederal sites). Less stringent cleanup would lower these projected costs; greater stringency would increase them. Their “best guess” of cumulative remediation costs for federal facilities is $240 billion for DOE sites and $30 billion for DOD sites.

The number of persons at potential risk of exposure to substances released from hazardous waste sites is imprecisely known. Using data from 1,134 NPL sites in 1991, the EPA estimated that approximately 41 million persons live within four-mile radii of 1,134 NPL sites, an estimate that was later revised upward to 73 million persons. A demographic analysis of persons living near 1,200 NPL sites led the ATSDR to estimate that approximately 11 million persons live within one-mile borders of these sites. A separate analysis by the ATSDR of 972 NPL sites found 949,000 children six years or younger live within one mile, which represented 11% of the population. This extrapolates to approximately 1.3 million young children living near the current 1,300 NPL sites. This is a large number of young children at potential health risk. Actual health risk must be determined by such factors as patterns of release of substances from sites, degree of exposure of persons in contact with released substances, toxicity of the substances, and individual susceptibility to a substance's toxicity.

Because substances released from hazardous waste sites can harm human health and the environment, prevention should be the operative word, with action in any program intended to reduce the toll of hazards on human health and ecologic systems. The public health literature well documents the fact that preventing a disease is usually less costly than treating it. This approach applies equally well to environmental hazards.

Preventing the production of hazardous waste through industrial recycling or preventing contact with any generated hazardous waste will obviously lessen any adverse effects on human health or the ecosystem. Furthermore, strategies to prevent contact can be implemented even after hazardous waste has been produced and released into the environment. For example, prompt interdiction of contact with the released substances can help minimize or prevent subsequent human health effects, and surveillance of exposed populations can be an effective early indicator of any adverse health effects.
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