

2 Controlling 3000 Chemicals One by One

One hallmark of contemporary America is the short life span of its crises. A problem emerges suddenly, builds swiftly to crisis proportions, briefly dominates public consciousness and concern, and then abruptly fades from view.

—Wall Street Journal

The number of potentially toxic substances is enormous. The number of commercial chemicals is 70,000. . . . Distressingly little is known about the toxic effects of many chemicals.

—The Conservation Foundation

One part per million: One drop of a toxic chemical in a barrel full of drops of pure water. One part per billion: One fine grain of a toxic chemical in a large bathtub full of grains of clean sand.

—An environmental scientist

The Toxic Chemical of the Month: Hexachlorobenzene

In 1973 I had been on the job at the EPA for less than one week when telephone calls from Louisiana started jamming the switchboard. The Governor and his aides challenged our competence. The state legislators gave us a piece of their minds. The farmers demanded redress.

Inspectors of the Food and Drug Administration (FDA) at a slaughterhouse in Texas had refused to certify shipments of beef originating in an area near Geismar, Louisiana, as “safe.” In turn, all

slaughterhouses in the region began turning back the Louisiana cattle. But the farmers had nowhere else to sell their cattle.

During routine chemical analyses of beef samples from the Louisiana herds, government scientists had detected the chemical contaminant hexachlorobenzene. They measured contamination levels of 0.1 to 6 parts per million (ppm). Since 0.3 ppm would have been reason enough to reject food according to the FDA, beef from Geismar was labeled as unsafe. But the FDA had established its “action level” of safety of 0.3 ppm several years earlier before the EPA had entered the scene. Now the responsibility for determining a safe level fell to the EPA, not the FDA. On the one hand, a bombardment of telephone calls to the EPA demanded that the Agency take steps to clean up the source of contamination. On the other, farmers challenged the original FDA action level as excessively conservative. They urged a new and more lenient level of safety.

Hexachlorobenzene was being discarded as a powdery waste from chemical plants. In this case, a large chemical complex of the Dow Chemical Company near Geismar had produced the noxious by-product. Cattle normally grazed in the fields alongside the many chemical plants punctuating the landscape. Trucks from a local company hauled the waste from the plant, along with wastes from many other plants in the area, to a landfill about 25 miles from the Dow plant. However, the haulers sometimes neglected to cover their waste loads during the trips so the powder blew across the fields en route to the disposal site. The operator of the landfill was also lax and simply piled the fluffy waste on top of other wastes without bothering to spread dirt on top of each load. On windy days the powder filled the air and drifted onto the fields. Twenty thousand grazing cattle had become contaminated from the powder.

One of the immediate tasks at the EPA was to determine a safe level for traces of hexachlorobenzene in food. Government inspectors urgently needed an acceptable level which they could use for certifying the safety of beef. At the same time, the Agency had to take action to put an end to the pollution of the countryside.

Agricultural officials in Washington, D.C. and Baton Rouge urged as high an inspection level as possible to minimize the rate of rejecting cattle, since each head was worth about \$500. As might be expected, the FDA was skeptical that any change in its old level of 0.3 ppm was

warranted. The EPA Administrator decided to seize upon this incident, and specifically the establishment of a safety level, as a highly visible demonstration of the Agency's sensitivity to the need to balance health concerns with economic considerations.

Meanwhile, the Dow Chemical Company pointed its finger at the waste hauler and the waste site operator. In Washington, Louisiana politicians were demanding special congressional legislation that would compensate the farmers for their losses.

The effects of hexachlorobenzene on humans were not well known at the time and are uncertain even now. In the 1950s a number of people in Turkey had accidentally ingested large quantities of the chemical with serious illnesses and a few deaths resulting. Several limited studies subsequently carried out in research laboratories with experimental rats suggested that human ingestion of the chemical over a long period of time at levels above 10 ppm could lead to serious illnesses and perhaps death in a manner akin to poisoning. However, no information was available concerning the possibility of deleterious effects of low levels in the range encountered in Louisiana.

In setting the original action level of 0.3 ppm, officials of the FDA had simply adopted a level used for other chemicals with similar molecular structures which scientists had studied more intensively. Ironically, the same FDA officials argued with great passion during discussions with the EPA that similar structures did not necessarily mean similar toxicities. Meanwhile, the World Health Organization had developed a guideline of 1 ppm as a safe level for the chemical. However, in probing the history of this international decision, specialists from the EPA discovered that the guideline was derived from the judgment of a group of medical experts who had met in Geneva. They had relied primarily on intuition rather than on documented scientific studies since there were no solid studies.

EPA staff members tried to trace the distribution of beef from slaughterhouses in Texas to consumers throughout the country. The idea was to show that by the time the Louisiana beef appeared on the dining room table, it would be so intermingled with other beef from uncontaminated areas that no individual consumer would repeatedly receive portions of meat with high traces of hexachlorobenzene. Therefore, the safe level might be higher than otherwise indicated. This analysis proved fruitless. While supermarket chains are excellent dilu-

tion mechanisms through the normal mixing of small cuts of meat from various sources, there was always the possibility that families who ate large amounts of meat would buy and freeze entire sides of beef from Louisiana.

Predicting how different safety levels would affect financial losses was even more speculative than estimating the health consequences of allowing different levels of contamination to pass safety inspections. Louisiana agricultural specialists had collected and analyzed hundreds of samples of flesh from the cattle in the field. Therefore, the EPA had a good profile of the levels of contamination within the herds and could estimate the number of cattle with contamination above 0.3, 0.5, 1, 2 ppm, and higher levels which were being considered for the action level. However, some of the cattle had been switched to clean feed, and EPA scientists did not know how to estimate the rate at which hexachlorobenzene would be flushed out of their internal systems. Thus, they had no basis for predicting how many cattle would have to be destroyed at different levels of safety. Also, neither Dow nor the state agencies would indicate the extent of economic relief, if any, which they would provide the farmers until the EPA established the action level. Finally, farmers always display remarkable ingenuity in cutting their financial losses when faced with economic disasters.

After several weeks of heated interagency debates in Washington, vociferous public meetings in Louisiana, and raucous sessions between EPA officials and the Louisiana congressional delegation, the EPA Administrator decided that 0.5 ppm was the appropriate level. Two considerations were pivotal in selecting this number. First, it was substantially below the guideline recommended by the experts assembled by the World Health Organization a few years earlier and therefore would appear to reflect the caution of the EPA when lives were at stake. Second, it was the highest number which the FDA would support regardless of financial losses. The views of the FDA were very important. The EPA was a new government agency trying to establish a sound reputation within a skeptical health community. Being aligned with the FDA, which was known for its caution on health issues, was a highly desirable goal.

Thus, when the time came to make the decision, economic factors were considered, but not very seriously. In retrospect, the downplaying of economic factors was warranted in this instance. Once the action

level of 0.5 ppm was established, the dire predictions of economic consequences disappeared. Immediately, farmers put their cattle on clean feed which quickly diluted the hexachlorobenzene concentrations to levels lower than 0.5 ppm in over 95% of the cattle. The state then purchased almost all of the remaining cattle for demonstration farms for retarded children who would observe but not eat the cattle.

This was my introduction to the “toxic of the month” approach that dominated the control of chemicals during the 1970s. As different chemicals were pinned down as the causes of problems in specific parts of the country, the federal government reacted, usually in a responsible manner. Unfortunately, the government seldom anticipated such crises and was almost always guided to problems by public outrage rather than by systematic study of the most threatening chemicals in the environment.

During the past decade, the hunt for toxic chemicals has been more far-reaching. At times it has seemed as if the government agencies have moved from the toxic of the month to the toxic of the day, and the number of chemicals subject to some type of regulatory controls by the EPA has grown to more than 3000. Many are used in pesticides. Many others are embedded in wastes being hauled away for permanent disposal. Still others are emitted into the air and streams at many industrial facilities. And a few are highly valuable chemicals used by businesses or even around the home where they must be handled with care.

During the 1990s the list of controlled chemicals will continue to grow, and the regulations governing how they are handled will become ever more complicated. In some cases, the chemicals will be controlled in groups. Sometimes the regulations will be highly specific to individual chemicals. But can the regulatory agencies, the manufacturing companies, and the interested public responsibly cope with such a large array of pollutants which are often characterized more by their differences than by their similarities? Do the agencies have the intellectual and financial wherewithal to develop hundreds and even thousands of customized approaches to deal with this chemical mosaic?

As we will see, recent history has shown that some chemicals must be singled out for individualized attention. They simply are too toxic, too pervasive in the environment, and too idiosyncratic in their behavior to be easily lumped with other chemicals which are targets for control. History has also demonstrated that alternative approaches are

needed to address the vast majority of the chemicals which may cause problems. The past experiences in dealing with individual chemicals which are discussed below should help set the stage for developing new strategies that will reduce risks from many more toxic chemicals in the future.

Containing One of the Most Toxic Pollutants: Dioxin

During the early 1980s, a serious problem erupted with a long-time toxic nemesis—dioxin. Times Beach, a few miles west of St. Louis, suddenly won the title of “pollution capital of the nation” and subsequently turned into one of America’s first toxic ghost towns.

The story began in 1969 when a small firm named North Eastern Pharmaceutical and Chemical Company took over a manufacturing plant in Verona, Missouri. Earlier the company had produced Agent Orange, a mixture of the plant-killing herbicides 2,4,5-T and 2,4-D, which was widely used as a defoliant to clear the vegetation on the battlefields in Vietnam. This chemical mixture was frequently contaminated with small amounts of dioxin. At the same time, Agent Orange was used in abundance, and the total amount of dioxin contamination was substantial.

Dioxin contains a wide variety of highly toxic molecules which have very similar structures. While toxicity varies from molecule to molecule, all are hazardous to some degree; and they are usually considered as a single pollutant, at least in the eyes of the public. Some of the very potent effects of dioxin, and particularly its genetic impacts, have been of concern for many years although the scientific debates continue to today over the extent that American army troops were exposed in Vietnam to dangerous levels of Agent Orange laced with dioxin. Indeed, several detailed studies were unable to attribute any health effects among American soldiers to the use of Agent Orange.

In 1969, the North Eastern Pharmaceutical and Chemical Company began producing another toxic chemical, hexachlorophene, for use in pesticides and cosmetics. This production process also generated substantial quantities of dioxin as a by-product. Until 1971 the company shipped its waste which was laden with dioxin to an appropriate chemical disposal facility. But then in order to save money the company

contracted with a small disposal firm—Independent Petroleum. This firm in turn subcontracted with a waste hauler from Missouri, Russell Bliss. His job was to take away oily sludge impregnated with dioxin which had accumulated on the bottom of the chemical mixing containers.

Bliss was not content simply to receive money for disposal of the waste—he adopted a new version of recycling. He sprayed the oily residues along the dirt roads and byways of Missouri in return for fees from local officials and residents who had discovered a low-cost, dust suppression program. In the early 1970s Bliss, in addition to spraying roads, coated several dusty horse arenas with his newly acquired oils, and hundreds of animals soon became sick and died. The state authorities sent soil samples from the horse arenas to scientists at a federal laboratory in Atlanta who found dioxin in the oil at levels far greater than the concentrations reported from the use of Agent Orange in Vietnam. Meanwhile, the attention of the federal and state agencies was diverted by the discovery of still higher levels of dioxin within the North Eastern manufacturing site at Verona. Prompted by such scrutiny, the owner of the plant began to treat the waste at the site at his own expense and successfully reduced the hazard. In the absence of additional reports of immediate problems, the issue of dioxin waned in the mid-1970s.

Several years later in 1979, dioxin again made headlines as the EPA began receiving new reports of dioxin contamination throughout Missouri. The agency launched a major investigation and began reconstructing the history of the dioxin problem in detail. Through an extensive sampling program, the EPA discovered particularly widespread dioxin contamination in Times Beach, a small community along the Missouri River.

Greatly exaggerated rumors of the effects of Agent Orange quickly spread throughout the community. Environmental sampling teams in protective gear resembling moon suits moved in next to children playing in backyards. The residents demanded that the “government” buy their homes so that they could move to a safe place. During the state election campaign in the fall of 1982, dioxin contamination took its place as a major political issue. A few politicians touted new chemical and biological sprays that would neutralize dioxin—an unrealistic claim. Most simply demanded compensation for the affected neighborhoods.

At that time, the extent of the health effects from exposures to low

levels of dioxin could only be inferred from previous investigations of the effects of dioxin in more massive doses. For example, following several industrial accidents a few years earlier which released dioxin at high levels into the atmosphere, some of the exposed workers had developed chloracne on the skin, a general sense of fatigue, disturbances in nervous system responses, and enlargements of the liver. Though these conditions seemed to recede after a few years, scientific studies with laboratory animals indicated the possibility that dioxin also caused birth defects and perhaps cancer at levels which were not much above the highest contamination levels in Times Beach. Meanwhile, medical studies of the residents of Times Beach uncovered no significant health impacts of dioxin.¹

Again, as with the case of hexachlorobenzene and the contaminated cattle, the key issue was to determine the level at which contamination was unacceptable. What level of dioxin in soil makes an area uninhabitable? Using as the point of departure results from studies of birth defects caused by dioxin ingested by monkeys, government toxicologists in Atlanta concluded that a contamination level of 1 part per billion (ppb) was the dividing line between habitable and uninhabitable. In their calculations they estimated the extent that dioxin would cling to soil, the likelihood that children playing outside would lick their dirty hands, and the possibility that the soil would be suspended in the air and breathed by residents.

Once the media had trumpeted the conclusions of the health researchers, the debate over habitability ended. For Times Beach residents, the implications of this health finding were clear. Since levels considerably higher than 1 ppb had been discovered in several areas of town, they were convinced that evacuation was the only course of action.

Who could challenge the views of medical experts employed by the federal government? They clearly preempted the responsibility of public officials to consider the social and economic implications in reaching an environmental decision, since residents simply would not live in areas pronounced by researchers to be unsafe. Buried in the pronouncement of the scientists was their decision that the concentration level at which dioxin might affect people should be 1000 times lower than the level that affected laboratory animals in order to provide an appropriate “margin of safety” for society regardless of the cost implications.

Finally, in February 1983 the EPA announced that it would buy the contaminated property where levels exceeded 1 ppb at prices reflecting land values before the contamination. After delays of some months, the federal government purchased the property, the residents moved out, and Times Beach was permanently cordoned off as a monument to the laxity of a chemical producer and the greed of a waste hauler who himself was soon carted off to jail.

The discovery of dioxin in Missouri triggered one of the biggest nationwide hunts for a single pollutant in history. Around the country, a major mission of each of the EPA's ten regional offices was to search out every conceivable source of dioxin. For several years the hunt continued. The EPA directed special attention to facilities which at one time had produced Agent Orange. Other pesticide production and processing plants were also implicated. In addition, the Agency targeted waste disposal areas for attention.

Soon dioxin was discovered to be a by-product of many waste incinerators. Indeed, some everyday combustion processes release trace amounts of dioxin into the air. And municipal incinerators which burn large quantities of plastics or wood products preserved with chlorophenol can produce significant dioxin emission. The implications of these findings were ominous, and the level of restrictions to be imposed on incineration of wastes remains a highly controversial issue.

Returning to soil and water contamination not only at Times Beach but also in many other parts of the country, the level of 1 ppb proscribed by the toxicologists becomes very important. The cleanup costs might be substantial even though the contamination is only slightly above the proscribed level. If the contamination level is slightly below 1 ppb, lack of action could mean the continuation of a health risk even if cleanup costs were very low. The researchers should not have been so quick to pronounce such a definitive level of safety based on limited scientific data—a level which can have tremendous financial and social implications for all concerned. As discussed in the next chapter, both researchers and policy officials must become more skilled in dealing with the uncertainties of risk evaluations and less prone to make definitive assertions as to the dividing line between safe and unsafe.

In summary, dioxin is one of the best examples of how the government has focused enormous resources on a specific environmental chemical. Its toxicity has caused anxieties wherever it has been un-

covered, and its historic association with Agent Orange has heightened political interest in its immediate containment. Now, as additional laboratory studies are reported, scientists are beginning to question whether the hazard of dioxin has been exaggerated.² However, to back off on the stringency of limitations which have been codified is politically very difficult for the government regardless of new scientific findings.

Setting National Standards for Toxic Air Pollutants

In many communities during the past two decades, the public has become aroused by dioxin, PCBs, hexachlorobenzene, and other toxic contaminants which threaten their well-being. However, the federal agencies began many years earlier to pay attention to a handful of other pollutants which could pose hazards for workers and for neighborhoods abutting industrial facilities. By the early 1970s, the EPA in particular had adopted a chemical-by-chemical approach to setting pollutant discharge standards as a cornerstone of the government's efforts to protect public health from toxic exposures.

Since that time, the EPA in very workmanlike fashion has identified hundreds of problem chemicals. The Agency has studied the likely health and ecological effects of each of these chemicals should they escape into the environment. It has estimated the extent people and natural resources are being exposed to individual chemicals, or will be exposed, if the substances are not contained. The Agency also considers the feasibility of various ways of controlling each chemical and then decides whether to attempt regulation of a particular chemical on a national basis. A good example of this chemical-by-chemical control method is the early regulatory action taken within the framework of the Clean Air Act.

In April 1973 the EPA limited emissions into the atmosphere of asbestos, beryllium, and mercury from industrial and other facilities. The Congress explicitly required that health concerns should take precedence over cost implications when considering hazardous air pollutants, and these three chemicals were the first to be addressed. Though scientific data as to their health effects were far from definitive, the EPA nevertheless imposed tight restrictions on emissions into the atmosphere.

First, with regard to asbestos, scientists had established a clear association between exposures of shipyard workers to asbestos and a higher-than-expected incidence of bronchial cancer. Also, they had shown that asbestos caused cancer of the membrane and lining of the chest and abdomen. Nonetheless, they had not been able to relate the amount of asbestos entering the body to the likelihood of cancer. Moreover, techniques for measuring levels of asbestos emissions from plant stacks had not been developed. Despite these uncertainties, the EPA developed an environmental standard that limited “visible” emissions from asbestos facilities. In short, an asbestos cloud—however faint—in the sky indicated a violation. Also, the EPA specified the types of technology which must be used to remove asbestos from emissions in order to reduce even the invisible emissions.

Turning to beryllium which is used in nuclear facilities as well as in other branches of industry, the U.S. Atomic Energy Commission had already established in 1949 0.01 microgram of beryllium per cubic meter of gases as their limit on emissions from plants under contract with the government. This limit was based on concerns over earlier reports that beryllium caused fibrosis and possibly cancer of the lungs of industrial workers. During the following 25 years, there were no reported cases of diseases related to beryllium among the populations living near these plants. The National Academy of Sciences reviewed the available information on the toxicity of beryllium and concluded that the original standard represented a safe level of exposure. Therefore, the EPA adopted the early limitation as the standard for all industrial facilities and, in effect, simply codified existing practices throughout the country in handling a potentially hazardous chemical.

Finally, with regard to mercury, the amount that is breathed must be considered together with trace levels that may contaminate food or water. An expert group convened by several U.S. government agencies in the early 1970s analyzed a number of episodes of mercury poisoning in Japan and concluded that 4 micrograms of methyl mercury per kilogram of bodyweight per day would result in the poisoning of a sensitive adult. They suggested that an exposure of about 30 micrograms per day for an “average” person weighing 70 kilograms or 154 pounds would be acceptable. This level would provide for a tenfold safety factor to compensate for the uncertainties in the scientific data being used. In addition to considering poisoning, the experts kept in mind the possibility of damage of the fetus.

At that time, a usual diet, together with drinking water, probably resulted in the ingestion of 10 micrograms of mercury per day, according to the experts. Thus, in order to restrict total intake to 30 micrograms, the average intake from air would have to be limited to 20 micrograms. If we assume the quantity of air inhaled through normal breathing as 20 cubic meters per day, the air could contain an average daily concentration of no more than 1 microgram of mercury per cubic meter. This level served as the basis for the standard.³

Thus, we see how the EPA customized the approach to setting the standard for each chemical depending on the character of the public health threat and the nature of the scientific information that was available.

During the next few years, the EPA slowly expanded its control of a few hazardous air pollutants as more problems were identified. In particular, the Agency established emission standards for benzene, vinyl chloride, arsenic, and radioactive chemicals. Then in the mid-1980s the EPA initiated greatly enlarged nationwide surveys of the extent of the air toxics problem. Specifically, the EPA searched for 45 specific toxic chemicals in urban air. The Agency attempted to estimate the cancer risks, but not other types of acute or delayed effects which are more difficult to identify, associated with exposures throughout the country to these air pollutants. The estimated cancer incidence was about 0.2% of the total national cancer incidence, an estimate that now seems high to many experts. As a result of these investigations, in 1985 the EPA decided that carbon tetrachloride, cadmium, chromium, chloroform, ethylene oxide, ethylene dichloride, butadiene, perchloroethylene, and trichloroethylene were next in line for regulation.⁴

The main problem highlighted by the EPA studies is the difficulty of isolating individual chemicals in the atmosphere as the cause of cancer or any other adverse health effect. There are so many different types of chemicals present in our cities from so many different sources that developing cause-and-effect linkages is usually impossible. Some chemicals seem obviously to be of more significance than others, based on their high levels of toxicity and the relatively large quantities of these chemicals in the air. According to the EPA, risks result in large measure from “complex pollutant mixtures typical of urban ambient air.”⁴ Thus, the chemical-by-chemical regulatory efforts of the past seem inadequate to address the problems now facing us. At the same

time, developing estimates of how risks could be reduced through specific regulatory measures to reduce emissions of individual chemicals or groups of chemicals remains a formidable problem.

As noted in the preceding chapter in 1989 the Bush Administration proposed a new and far-reaching approach to the control of toxic air pollutants. If this proposal is adopted by the Congress, restrictions will be imposed on emissions of over 190 chemicals through an approach that calls for industry to use the most effective technologies for cutting emission levels. The industries responsible for emissions of these chemicals will be required to install technology mandated by the government to limit their discharges, technology referred to as "maximum achievable control technology." For new facilities, such a requirement means that controls must be at least as stringent as the best emissions control already achieved in practice by a similar facility anywhere in the country. For retrofitting existing plants, controls must be as stringent as controls "typical" of the best performing technologies at similar facilities already on-line. Limitations on discharges from those facilities which are in ten categories deemed to be the worst sources of toxics will be in place within two years, and limitations on the other facilities within five to seven years. Once these controls are installed, the government may take further steps to reduce any residual risks from toxic emissions.

This highly desirable change in the Clean Air Act takes the initial steps in avoiding the endless debates of the uncertain health hazards of individual chemicals while relying on the demonstrated capability of industry to reduce hazards without further delay. Controversy will continue over whether there are significant residual risks from escaping pollutants after the new technologies are in place, but much of the emissions problem will have been solved. The experts will never be able to determine with certainty which chemical mixtures are safe and which are hazardous. We do know that chemical air pollutants are seldom if ever beneficial. If some plants are capable of employing stringent controls and still remain in business, then other plants should be expected to perform with comparable efficiency.⁵

These controls are limited to industrial sources which are responsible for only a portion, perhaps 25%, of toxic air pollutants. Sewage plants and electrical utilities, for example, will not be included, and the status of dry cleaning establishments and gasoline stations is unre-

solved. Separate regulatory action is being directed to motor vehicles which are responsible for up to 50% of the health impacts from air toxics, according to the EPA—benzene, diesel fumes, and other hydrocarbons. A principal initiative in the proposed Clean Air Act in this regard is the call for greater use of clean fuels, and particularly blends of gasoline with methanol and ethanol.

A very serious step has been proposed to control air toxics. Also, the important principle of controlling toxic chemicals in large groups, in this case a group of almost 200 pollutants, using proven technologies has been strongly reinforced.

Regulating Categories of Chemicals

Historically, environmental protection efforts have spawned separate programs to control chemicals which pollute the air, those which degrade water resources, those which show up in solid wastes, and those which are used in drugs, pesticides, or food additives. Thus, chemicals have been placed in groups for regulatory purposes and are subject to different laws according to how they are used or how they reach the environment.

Frequently, however, the same chemicals appear in many forms—in air, in water, in food. Hence, they attract regulatory attention under several laws. In some cases a single chemical may be regulated under as many as ten different laws. The ground rules for regulating a chemical may vary from law to law.

Uncertainties as to how chemicals behave in the environment further complicate the control of chemicals which move with alacrity from environmental compartment to compartment. Will airborne lead contaminate vegetable gardens? Will cadmium in river sediments be stirred up and make fish inedible? Will solvents buried in waste sites vaporize and leak through cracks in the soil into nearby neighborhoods?

Fourteen years ago, the Toxic Substances Control Act was designed as an umbrella law—to bridge regulatory gaps and reduce legal redundancies which too often had prompted governmental stuttering in the control of chemicals that the public may encounter in many different forms. Congressional expectations that the requirements of different laws would be easily meshed through this new regulatory authority

have been excessively optimistic. Bureaucracies in general, and regulatory bodies in particular, resist coordination efforts no matter how many details are spelled out in law. Only now, after many years of conflict and confusion as to how chemicals are to be constrained under a variety of laws, have the EPA and the other regulatory agencies begun to integrate their efforts on a broad basis to address many chemicals that fall within different regulatory groupings.

The need for other types of groupings of chemicals became obvious during the debates which led to the enactment of the toxic substances legislation: many pollutants should be regulated in clusters rather than as individual chemicals. More than 70,000 chemicals are used throughout the country. Thousands of chemicals are discharged into the environment as by-products of manufacturing processes. Many more new chemicals are being developed in research laboratories. Hence, total reliance on one-by-one regulation is simply not practical.

Of initial interest were groupings of organic chemicals with similar molecular structures which, it is believed, have similar although not identical toxicity characteristics. Peroxides and azo dyes, for example, were identified long ago as categories of chemical compounds that include many individual chemicals worthy of regulatory scrutiny. While each chemical has unique properties, many chemicals within a single category pose similar problems.

As previously noted, PCBs and dioxin are mixtures of closely related chemicals. While the individual chemicals in each of these mixtures may have somewhat different toxicological characteristics, most of them are harmful if handled improperly. More than one of the constituent chemicals are invariably present, and formidable problems arise in the laboratory in distinguishing precisely among the individual chemicals which make up the mixtures. Thus, trying to develop a different level of control for each of the dozens of constituents is seldom worth the effort.

However, federal agencies have been hesitant to treat chemicals as groups which are based on similarities in their molecular structures. Of course, when nothing is known about a chemical except the character of its molecules, specialists draw inferences as to whether there may be a hazard based on the known toxicity of similar molecules. But these inferences cannot always stand up as regulatory judgments.

As we will see, risk assessment methods have relied on intensive

investigations of individual chemicals with discrete molecular structures. Regulatory actions traditionally depend on such assessments, and lawyers are comfortable defending governmental actions which rely on laboratory studies of chemicals one by one. Extrapolating laboratory findings of toxicity from one chemical to another opens up many scientific avenues for challenge.

In several cases, the EPA has addressed groups of chemicals with closely related structures. For example, over the years the EPA has identified general categories of chemicals which include at least some chemicals with toxicities of concern. The EPA then has required industry to carry out specified types of laboratory tests of other chemicals that fall within these main groups in order to determine, one by one, their toxicities. As another example, the EPA reviews the properties of new chemicals which any company plans to produce. As part of the process for determining the need for regulatory action, the government scientists compare the molecular structures of the proposed new chemicals with the structures of other chemicals which have been shown to be either problems or, on the other hand, environmentally benign.

Turning to the effects that toxic pollutants have on humans, no grouping of chemicals has received more notoriety in Washington or throughout the country than carcinogens, or chemicals which cause cancer. For two decades the debates have raged, with cynics arguing that man is not a giant rat who develops tumors as readily as do experimental animals in response to environmental chemicals. Scientists rightfully argue that while laboratory experiments have their limitations, experiments on laboratory animals provide the best approach for clarifying the biological impacts of chemicals other than using human subjects for experimentation purposes.

First a handful, then several dozen, and now several hundred chemicals have been indicted by government agencies as carcinogens. About two dozen of these have been shown directly through studies of their effects on humans to cause cancer in humans with the remainder being of concern due to the potency they have demonstrated in the laboratory. Qualifying words such as "probable" carcinogens or "weak" carcinogens are sometimes included in the indictments to take into account uncertainties. Once a chemical is considered by the EPA or another regulatory agency to show signs of carcinogenicity, various types of regulatory restrictions may take immediate effect. As an ex-

treme, chemicals with even the slightest carcinogenic tendencies are simply banned by law from use in food additives.

Volume of production is another criterion that has been considered for grouping chemicals of high toxicity. Toxic chemicals which are produced in large quantities may be of more concern due to the possibility of accidents during manufacture, shipment, or storage than chemicals produced in very small quantities and not shipped around the country. Also, the Toxic Substances Control Act exempts from some regulatory requirements chemicals produced only in small volumes for research purposes.

Finally, the likelihood of chemicals coming into direct contact with humans or ecological resources provides a strong rationale for grouping these chemicals for regulatory purposes on the basis of "exposure." For example, chemicals which are deliberately dispersed into the environment such as aerosol propellants should be of more concern than chemicals of comparable toxicity which remain contained within sealed vessels in chemical plants. Chemicals which come into close contact with people such as newspaper inks, dyes, and household cleansers have a greater potential for causing problems than those which only reach people accidentally. Also, chemicals used in open areas such as solvents and paints are usually more worrisome than chemicals which are not in continuing contact with the atmosphere.

Regulatory agencies, and particularly the EPA, have considered all of the foregoing approaches for categorizing chemicals. However, the agencies constantly hesitate over the scientific defense of their conclusions if they attempt to address too many chemicals simultaneously. Meanwhile, industry leaders are skeptical of any schemes that would enable the EPA to broaden its regulatory net for capturing more chemicals through grouping or any other approach.

At the root of the restrained approaches of the agencies in trying to limit groups of chemical pollutants is the preoccupation of scientists with individual chemicals during the risk assessment process. They have become used to studying chemicals one at a time. But the public is seldom exposed to chemicals one by one. Approaches to risk assessment which take into account exposure to different levels of many chemicals with different toxicities are much more complicated, but they would be much more realistic. Greater attention to this neglected problem, and specifically greater reliance on epidemiological studies of

what is really happening to people in polluted areas, is essential to undergird more effective control of the large numbers of potentially harmful chemicals which are contaminating the environment.

Waste Products Laden with Hazardous Chemicals

The difficulties in addressing chemicals one by one become especially apparent in the control of solid and liquid wastes—wastes often containing dozens of chemical pollutants. As a starting point, the EPA and state environmental agencies have prepared long lists of regulated waste chemicals. These lists encompass over 1000 chemicals including all of the well-known problem chemicals of the past—toxic metals, pesticides, and corrosive acids, for example. Chemicals that leach from plastics discarded by every household are listed, and the waste solvents from dry cleaning establishments are itemized. Many other chemicals found in “ordinary” trash and in the by-products of every municipal sewage treatment plant are included.

The EPA’s regulations prohibit the disposal into the ground of several hundred chemicals in order to ensure that groundwater will be protected from the most dangerous pollutants. These pollutants must be incinerated at high temperatures, chemically decomposed, or reclaimed for further beneficial use. Companion regulations specify methods for determining whether other chemicals or specific types of waste streams which contain chemicals should also be considered hazardous. If they are, they are destined for disposal in waste sites meeting specifications for maximum containment. Still other regulations simply require industrial facilities to publicly declare the quantities of certain chemicals that they are discharging into the atmosphere or into streams or are sending to landfills.

The lists of waste chemicals have triggered many actions by the federal agencies, state authorities, industry, and the scientific community. Numerous studies are under way to characterize the toxicity of the individual chemicals and their mobility once they are in the environment. At what concentrations will they harm humans or ecological resources? Will they explode or catch fire at high concentrations? How easily can they move through the environment—through water and through soil? Will they decompose as they come into contact with other chemicals? What materials can be used to contain these chemicals?

Some of these chemicals have been studied by the government for years. Library shelves are piled high with reports of the health and environmental effects of hundreds of toxic chemicals. Indeed, a cottage industry of firms along the beltway of Washington, D.C., thrives on revising studies of individual chemicals for government agencies and industrial organizations which are suddenly confronted with chemicals that have been problems for others in the past.

Most studies are directed toward individual chemicals even though waste products are usually contaminated with many chemicals. However, the problems of hazardous wastes are not simply the sums of the problems posed by individual chemicals. These chemicals can interact with one another. Also, the solutions to hazardous waste disposal problems may not be obvious from studies of individual chemicals, for measures that will successfully contain or destroy some chemicals may be ineffective for controlling others.

Meanwhile, chemists are hard at work developing better, cheaper, and faster methods for analyzing waste products in order to determine which chemicals are present and their concentrations. They have become keenly aware that their techniques must simultaneously identify large numbers of chemicals in the wastes. For example, an analytical technique called x-ray fluorescence permits identification of two dozen toxic metals. Sometimes, however, a highly specialized technique is needed to identify a single chemical such as mercury. Mass spectrometry is a particularly important analytical method. It permits identification of hundreds of organic chemicals including both chemicals which were suspected all along of being present in the waste and chemicals which show up unexpectedly.

If very low concentrations are of concern, such as in the case of dioxin, development of very expensive laboratory techniques to identify and measure the chemical may be required. In 1984, for example, the EPA's Las Vegas laboratory spent \$750,000 to purchase a triple sector mass spectrometer for measuring trace quantities of dioxin. Of course the instrument could also be used to find other pollutants as well although at high costs. The real problem, however, was not cost, but rather finding a scientist with enough experience to operate this highly sophisticated instrument which was still a novelty in the analytical chemistry community.

Even when armed with sophisticated assessment tools, scientists face formidable problems in analyzing wastes. Abandoned hazardous

waste sites come in all configurations and contain every conceivable mixture of chemicals. Sometimes the history of dumping can be reconstructed, and reasonably good information is available on the contents of the site—at least as it was at the time of disposal. In many cases, however, the contents of corroding drums are not known, particularly if the disposal dates back many years; and the EPA has uncovered many examples of the pumping of liquid wastes of unknown origin into pits which were then covered with dirt. Thus, the laboratory chemist may have little advance warning of what he or she is looking for. Also, before the sample arrives at the laboratory, it may begin to disintegrate. Crude techniques for removing the sample from the waste pile may result in the loss of pollutants or the addition of sample contaminants, and less than perfect techniques for preserving the sample in its original form may result in changes in the sample en route to the laboratory.

A related concern is the huge volume of hazardous wastes in America's 6500 municipal landfills. The volume of trash in these dumps is so large that determining, let alone correcting, the toxics problem at any site seems like an insurmountable task. On a national basis more than half of our municipal trash is classified as paper, paperboard, and yard wastes. Substantial quantities of glass, food, and textile wastes are also present. The EPA has estimated that a community of 100,000 people deposits almost 500 tons of hazardous wastes in addition to non-hazardous waste in landfills each year. These sites were not designed to contain leaks, and the resources of communities to correct past sins are in very short supply.

An immediate problem both at hazardous waste sites and at landfills is to determine whether harmful chemicals are leaking from the disposal areas—leaking into the air, into nearby surface waters, or into the groundwater. Based on knowledge of some of the contents of the site, scientists usually concentrate their efforts on monitoring for a few “indicator” chemicals, chemicals which are known to be present in the waste and which do not decompose as they are washed or blown through the environment. The presence of these chemicals outside the site suggests that other chemicals may be leaking out as well. Highly toxic chemicals are often selected as indicator chemicals since discovery of a potential hazard off-site immediately buttresses the legal case for forcing prompt corrective action and for penalizing the dumpers.

Waste disposal is currently conceived as a problem of chemical

containment although we hope that someday destruction of most wastes may become technically and economically feasible. The identification of the hundreds and eventually thousands of chemicals of concern is a sensible first step. If engineers could indeed contain all of the currently identified chemicals for the indefinite future, the hazardous waste problem would be largely solved. However, during the 1990s financial resources are not unlimited, and only modest steps toward controlling large quantities of so many chemicals in so many locations will be possible. These steps should focus on containing the maximum number of chemicals which pose a threat. This strategy both relies on and transcends chemical-by-chemical control.

Let us now turn to a specific example of how my colleagues at the EPA and I attempted to determine the hazards at a waste site by assessing the problems posed by individual chemicals and then by aggregating these findings.

150 Chemicals Told the Story of Love Canal

In June 1980 I was one of four EPA managers whom the EPA Administrator summoned to his office in Washington where we received instructions to carry out a crash study of the safety of a residential area of about 600 homes in Niagara Falls. These homes surrounded a previously evacuated area of 100 homes immediately adjacent to Love Canal. The Congress, the local authorities of Niagara Falls, and many scientists were vigorously criticizing previous studies of the area carried out by the state of New York and several EPA offices: the environmental sampling was faulty, quality control over the laboratory analyses was inadequate, and unwarranted conclusions were drawn from inadequate data, according to the critics. Now the EPA would devote the full resources of its research laboratories to "do it right," so the Agency promised.

The EPA's Las Vegas laboratory, where I was the Director, was responsible for improving monitoring programs at hazardous waste sites throughout the nation. On the airplane flight to Washington, I reviewed our earlier experiences in designing large monitoring programs to assess toxic chemical contamination. I was particularly concerned as to how the field teams would take samples of soil, water, and

air around homes occupied by people who were already very upset and scared without further aggravating the situation.

As we assembled on the eleventh floor of the EPA headquarters, the Administrator and the Deputy Administrator were waiting. The Deputy quickly took charge, enunciating a very simple message: bring back the answer prior to the November presidential election as to whether residents of the area should be relocated. The good news was that there would be no political bias in the way our specialists designed and carried out the monitoring study. The bad news for us was that there were no new funds for the program, and we would have to find the money in our laboratory budgets. As we will see, the bad news for the Deputy Administrator, which we broke to her slowly in the weeks that followed, was that her deadline of four and one-half months for completing the study was impossible even if we had unlimited financial and personnel resources at our disposal.

During the next year, the four of us—three laboratory directors from Research Triangle Park in North Carolina, from Cincinnati, and from Las Vegas, and our chief in Washington—were fully engaged in finding toxic chemicals in that residential area and in explaining the significance of our findings. Many scientists on our staffs, at other EPA laboratories, and from private contractors supported this massive effort which left an indelible imprint on future approaches to environmental monitoring at waste sites.

In this area of about two miles by two miles surrounding Love Canal, the hunt for toxic chemicals was relentless. EPA specialists sampled the air near the Canal, between the houses, and along the roads. They removed samples of soil in yards, in fields, and in the schoolyard. To test the runoff from sewage and storms, they went into underground culverts in protective clothing. They scooped water from the river and streams and collected bottles of water from drinking water taps. The drilling of 175 sampling wells through yards and into shallow and deep groundwater was a particularly daunting experience. They also trapped and skinned field mice and took on the tasks of collecting earthworms and maple leaves which biologists advised were possible collectors of foreign chemicals.

Inside the homes they placed air samplers in bedrooms and living rooms. They probed into basement sumps. They positioned potatoes and oatmeal in places where food might absorb toxic fumes. They even

shaved hair from pet dogs of the neighborhood in the search for accumulations of toxic metals.

Then EPA chemists shepherded many thousands of samples through analytical chemistry laboratories in distant parts of the country. Quality control was the byword. Every measurement was documented and cross-checked with other measurements. Questionable measurements were repeated or were discarded.

Meanwhile, other specialists collected supplementary information to provide a context for the chemical information. Hastily erected meteorological stations provided information on wind patterns in the area. Aerial photographs and topographic maps revealed depressions on the ground that could influence the movement of chemicals. Geophysical instruments sent radar signals, acoustic waves, and electromagnetic impulses into the ground to help us understand the flow of groundwater in the region.

Our instructions were very clear on one point. We were not to study the people: no blood samples, no urine specimens, no medical examinations. The local population had already been through such health surveillance several times. The earlier medical findings were repeatedly challenged as scientifically flawed and had led only to great confusion and controversy. The experts simply could not agree on the types of medical studies which would be useful in reaching a judgment on whether pollution had become a threat to public health. Therefore, the monitoring program was simply to characterize the chemical environment as the basis for an assessment of the habitability of the area. Of course, the study of the presence of pollutants was also to lead to conclusions about leakages of chemicals from the waste pile into the inhabited areas.

During my military service following World War II in Germany, I spent many days and nights in command centers surrounded by tanks, jeeps, artillery pieces, guards carrying gas masks, and barbed wire. At the Love Canal command center, I was surrounded by water tankers, dump trucks, bulldozers, drill rigs, police cars, fire engines, workers in moon suits, and high fences. In Germany, I had been concerned about potential foes behind the iron curtain. At Love Canal, we were facing very different adversaries, toxic pollutants and aggressive lawyers representing an irate public.

Returning to the design of the study, the initial task was to identify

the chemicals to be placed on the detection “hit list.” We reasoned that if we could determine the concentrations of the principal chemicals which were present in the area, then the toxicologists and the medical doctors could decide whether the levels were above or below thresholds of safety. But we had to decide in advance which chemicals would be the targets of the investigation so that our specialists could select the appropriate sampling and analysis equipment and techniques. For example, searching for a toxic metal which is as stable as a rock is different from probing for a chemical which turns into a gas when disturbed. Also, highly reactive acids need to be collected in different types of containers than inorganic salts which do not trigger similar reactions.

The process for selecting chemicals which were likely to be present in the area seemed obvious. First, available records identified dozens of chemicals which had been dumped by the Hooker Chemical Company into Love Canal many years earlier. Among those deposited in the largest volumes were the pesticide lindane and the industrial chemicals chlorobenzene, benzylchloride, sodium sulfhydrate, and dodecyl mercaptan. Second, the EPA had the results of earlier monitoring in the general area by New York state environmental specialists. Even though the thoroughness of these studies was being challenged, they nevertheless persuasively indicated the presence of other compounds and particularly toxic metals. Also, we had preliminary information on the chemical composition of liquids draining from the canal into a nearby collection system. Thus, we had a good starting point for preparing the initial hit list.

But as previously noted, the EPA was under siege by the Natural Resources Defense Council to search for the 125 priority pollutants throughout the nation’s waterways. Some of these chemicals were already on the hit list. Many analytical laboratories which we had engaged for the effort were ready to analyze samples for all of the priority chemicals for a package price, and therefore we simply included all 125. Finally, as already noted, the EPA was seized with the problem of minute traces of dioxin throughout the country, and rumors were circulating that nuclear refuse had been placed in Love Canal at the end of World War II. Why not include these two categories of chemicals—dioxin and radioactive wastes—even though sampling for them required special handling procedures and the analyses required special

laboratory techniques? So we included them as well in order to head off later criticism of inadequacies of our investigations.

We predicted that skeptics of the EPA's competence would still contend that the study had missed some chemicals. Indeed, within a few days after we received the assignment to carry out the study, staff members on Capitol Hill and government scientists in agencies other than the EPA began sniping at the approach we were developing. They argued, for example, that perhaps some chemicals placed in Love Canal many years earlier would decompose into other chemicals and these decomposition compounds would leak into the environment.

Therefore, we developed a last line of defense. We required each laboratory carrying out gas chromatography–mass spectrometry analyses, a technique which compared the peaks recorded on the computer screen as the samples were analyzed with peaks expected from the target chemicals, to also report unexpected peaks. These new peaks would indicate the presence of chemicals that had not been targeted in the study, EPA chemists correctly hypothesized. Thus, we would argue, no contaminants could slip through our net.

The sampling began in August 1980 and concluded by the end of October. We knew that such an extensive monitoring effort should never be conducted in such a rush. It should have been carried out in stages so that preliminary findings could guide more detailed investigations and so that sampling could take place in each of the seasons of the year as water runoff conditions vary. We truly needed one year on the site. But the political pressures for immediate results from the EPA Deputy Administrator and from the Congress were enormous. Therefore, after we had the concurrence of the state and local authorities and the reluctant cooperation of all local residents to go into the area, the EPA field teams simply had to move in and pull out as quickly as possible. Once the sampling was accomplished, the EPA scientists spent the next eight months analyzing the hundreds of thousands of bits of information which the chemical laboratories generated.

During this period, all the strengths and weaknesses of chemical-by-chemical analyses came to the fore. The program was highly successful in characterizing the area in general since the total number of chemicals which were investigated simultaneously was quite large, namely 150. On the other hand, considerable difficulty arose in explaining the origin and significance of local hot spots where a few

chemicals were present and others which had been expected were not. Finally, the government did not equivocate in drawing conclusions as to the health implications of the findings as discussed below, but the basis for judging the potential problems associated with exposures to multiple pollutants at very low levels was a gray area for even the most sophisticated scientists.

In the end, the EPA concluded that the residential area of 600 homes was not being polluted as a result of Love Canal, and the Agency summarized the findings of the study as follows:

. . . the (inhabited) area exhibited no clear evidence of Love Canal-related contamination Also, the data revealed that the occurrence and concentration levels of monitored substances . . . could not be attributed in a consistent fashion to the migration of contaminants from Love Canal. . . . Finally, the data suggested that the barrier drain system surrounding the landfill was operating effectively to intercept the lateral migration of contaminants from Love Canal. . . .⁶

These findings did not suggest that there were no man-made contaminants present in the inhabited areas. There were trace levels of many chemicals as is the case in all industrial areas of the United States. The findings showed rather conclusively, however, that the trace levels in the inhabited area could not be attributed to Love Canal.

Of course, the residents immediately wanted to know the public health significance of the contamination even if it was attributable only to general industrial pollution and not to the Canal. This same question had been asked before in other industrial communities, and health experts had always been reluctant to respond. The EPA had engaged a special contractor to conduct risk assessments of the findings of trace levels of the contaminants which were discovered near Love Canal, but the contractor gave up on the grounds that not enough was known as to how often the population came in contact with the chemicals.

The task of making a public pronouncement on the safety of the area based on the data we had collected fell to a senior government scientist from the Centers for Disease Control in Atlanta. Unlike many experts, he did not dodge the issue. His message was clear and unequivocal. There was no health risk from the chemical contamination.

The EPA had uncovered very low concentrations of several dozen contaminants (but not dioxin or any other equally potent chemical)—in

the parts-per-billion and tens of parts-per-billion ranges. In the view of this medical expert, these levels were well below the threshold of concern. In public discussions he argued that the levels were consistent with levels found in other industrial cities around the country and there was no basis for believing that special health problems due to pollution existed in any of these areas. He later confided to us that only if the measurements had shown levels 100 times higher in the parts-per-million range would he have been concerned.

Still, some residents were not satisfied. The EPA had found a few samples in backyards which had contained one or two chemicals with concentrations 10 to 100 times higher than the average, and the residents wanted to know what these abnormal measurements meant for them. Also, in several areas we found low levels of eight or ten organic chemicals, and residents wanted to know the meaning for them when these measurements were aggregated. We could not provide satisfactory responses to their questions. In almost every environmental monitoring program in industrial areas, occasional high values of individual chemicals or aggregations of chemicals are discovered. The experts simply do not have good answers for questions that inevitably arise concerning an occasional exposure to these high values.

In general, the program was successful—scientifically and politically. The focus was on individual chemicals, but on so many that the comprehensiveness of the investigations could not be challenged. However, the program was unique, given the enormous effort expended by the EPA in carrying out the monitoring studies. Seldom will such high levels of scientific expertise and financial resources be available. The challenge is to adapt the approach of studying a “sufficient” number of individual chemicals for environmental assessments which are less well endowed.

Controlling the Most Toxic Chemicals with Concern for Many More

As we have noted, in a strict sense each chemical is different. It behaves in its own unique way. Each affects humans and ecological resources differently. Often, however, these differences are far more important to the scientist than to society. In some cases even the chem-

ist has difficulty distinguishing one molecular structure from another let alone describing the differences in the environmental impacts of similar chemicals. While toxicologists and botanists have made impressive advances in determining the adverse effects of a few chemicals, they struggle with little success in predicting the synergistic effects of chemicals acting in unison on biological species.

Whether we are addressing toxic air or water pollutants, hazardous wastes, pesticides, industrial chemicals, or contaminants widely dispersed throughout the land, our nation's strategies for coping with environmental pollution must involve both control of individual chemicals and control of groups of chemicals. Some pollutants are simply too toxic not to receive special attention. At the same time, the number of potentially hazardous chemicals is too large to customize every regulatory approach to unique molecular structures.

Ideally, in their efforts to control groups of chemicals, regulatory agencies simultaneously constrain the individual pollutants of greatest concern. But this is not always the case. The level of control required for highly toxic chemicals may exceed the control levels imposed on other chemicals in the groups.

Also, placing limitations on the most toxic chemicals should address the most serious problems. But this also is not always true. The aggregated impacts of combinations of the less toxic chemicals have yet to be adequately explored.

The next chapter addresses the central issue in the control of chemicals—the magnitude and character of risks which they pose. However, the uncertainties associated with risk assessments are usually great. Consequently, the nation is often faced with a dilemma. Excessively stringent action to regulate individual chemicals may divert too many financial resources to environmental protection while inaction can lead to a more dangerous situation in the future. Controlling groups of chemicals by requiring industry to use the best available control technologies without trying to define the precise level of risk, as is now required under the Clean Air Act, is one concrete example of how this dilemma might be addressed in the future.

At the same time, governmental overreaction to health threats from individual chemicals needs to be tempered. For example, the tens of millions of dollars currently being spent to rip asbestos insulation out of schools and public buildings throughout the country exemplify how

well-intended efforts have gone out of control simply because it was easy to peg “corrective” actions to a specific chemical. Asbestos can be a serious problem when it breaks up and enters the air; but as long as it is embedded in solid building materials, the best strategy is to let it remain for the lifetime of the material and then arrange for careful disposal.⁷

On the other hand, a responsible approach focused on a single chemical has been adopted by the Congress in controlling lead in drinking water, with particular attention to exposures of children and pregnant women. Specifically, legislation requires repair or removal of water coolers with lead-lined tanks and a ban on future sales of such coolers. There are alternative products. Also, the legislation provides funds for medical screening of children and calls for remedial action when problems arise involving lead in plumbing and in kitchen facilities.⁸

10. See, for example, "Toxic Substances: EPA's Chemical Testing Program Has Made Little Progress," U.S. General Accounting Office, GAO/RCED-90-112, April 1990.
11. "Settlement Agreement," Civil Actions 2153-73, 75-0172, 75-1698, and 75-1267, in the United States District Court for the District of Columbia, June 7, 1976.
12. Marx, Jean L., "Drinking Water: Another Source of Carcinogens," *Science*, November 29, 1974, pages 809–810.
13. For early EPA efforts to control toxic chemicals, see "Summary Tabulation of Selected EPA Activities concerning Toxic Chemicals," Office of Toxic Substances, EPA, April 1976.
14. "Environmental Group Ranks Toxic Pollutants," *Washington Post*, August 11, 1989, page A10.
15. "Taking Inventory of 7 Billion Toxic Pounds," *USA Today*, August 1, 1989, pages 6A–7A.

Chapter 2

1. Long, Janice R., and David J. Hanson, "Dioxin Issues Focus on Three Major Controversies in US," *Chemical and Engineering News*, June 6, 1983, pages 23–36.
2. Gladwell, Malcolm, "Scientists Temper Views on Cancer-Causing Potential of Dioxin," *Washington Post*, May 31, 1990, page A3.
3. Schweitzer, Glenn E., "Toxic Substances: Legislation, Goals, and Case Studies," *A Framework for the Control of Toxic Substances*, Office of Toxic Substances, EPA, April 1975, page 4.
4. Berry, D. Kent, "Air Toxics," *Environmental Science and Technology*, Volume 20, Number 7, 1986, pages 647–651; also, see "National Emission Standards for Hazardous Air Pollutants," EPA, 40 CFR Part 61, September 14, 1989, for a discussion of technical considerations in setting a benzene standard as an example of current regulatory approaches.
5. Ember, Lois R., "President's Clean Air Bill Gets Mixed Reviews," *Chemical and Engineering News*, August 7, 1989, page 26.
6. *Environmental Monitoring at Love Canal*, Volume 1, EPA 600/4-82-030A, EPA, May 1982, pages 21–22.
7. Abelson, Philip H., "The Asbestos Removal Fiasco," *Science*, May 2, 1990, page 1017.
8. "Lead Contamination Control Act," EPA 570/9-89-AAA, EPA, July 1989.

Chapter 3

1. Technical documentation about the vinyl chloride case is included in: "Preliminary Assessment of the Environmental Problems Associated with Vinyl Chloride and Polyvinyl Chloride (with Appendices)," EPA, September 1974.
 2. A good discussion of the pervasiveness of PCBs in the mid-1970s is included in Maugh, Thomas H., "Chemical Pollutants: Polychlorinated Biphenyls Still a Threat," *Science*, December 19, 1975, page 1189.
-