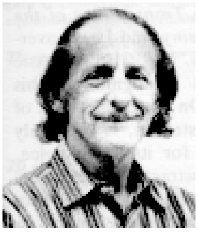
Essays of an Information Scientist, Vol:9, p.253, 1986
Current Contents, #34, p.3-9, August 25, 1986



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Hazardous Wastes. Part 1. The Poisoning of Our Planet

Number 34 August 25, 1986

Readers of *Current Contents®* (*CC®*) have often heard me praise Philadelphia's cultural and scientific achievements. While I take great pride in these and other local accomplishments, Philadelphia, like most other cities, does have its share of problems such as waste disposal. But if we are slow to act in the face of this public health issue, overcoming our complacency toward wastes that are invisible, as are most chemical and radioactive materials, is even more difficult. These wastes are all the more insidious since they usually cannot be tasted in contaminated food and water or smelled in the air.

Hazardous wastes have developed into one of the largest problems facing modern society. According to Samuel S. Epstein, Department of Preventive Medicine and Community Health, University of Illinois Medical Center, Chicago; Lester O. Brown, House Commerce Committee, Subcommittee on Investigations; and Carl Pope, science writer, Sierra Club, approximately 80 billion pounds of hazardous wastes are produced in the US each year.[1] (p. 7) The Environmental Protection Agency (EPA), Washington, DC, estimates that only 10 percent of these wastes are disposed of safely.[1] (p. 9) The extent of the hazardous-waste problem and our inadequate disposal techniques are constant reminders of our preoccupation with abundance and our subsequent failure to take responsibility for its consequences.

These consequences pose questions for environmental and health researchers as well as for political and economic analysts. Surprisingly, the life-threatening and broad-ranging significance of this research topic is reflected in a relatively small number of scholarly publications. A check of the *ISI®* online database *SCISEARCH®* shows that only about 625 papers on hazardous wastes have been published between 1974 and 1986. Almost half of these papers have appeared in the last two years. While this might indicate that we are paying more attention to the problem, in reality we have only begun to scratch the surface of this vast topic.

Although now there is a relative scarcity of hazardous-waste research literature, I am optimistic that this field will begin to build momentum. I believe that advances in knowledge and its dissemination can help to provide solutions. In Part 1 of this two-part essay, we will discuss the types of hazardous waste and how they affect the ecosystem. In addition, we review current US federal regulations concerning wastes. In Part 2 we will briefly describe various waste-disposal technologies, as well as how other countries cope with waste disposal. We will conclude by identifying the core literature and research fronts related to hazardous wastes.

Definition of Hazardous Wastes

Since the beginning of the industrial revolution, waste has been an inevitable by-product of virtually every major economic sector, including agriculture, commerce, industry, and the household. Every process for producing useful items, such as clothing, food, and drugs, also creates potentially dangerous material. The manufactured product itself may be dangerous, such as unused pesticides in storage that leak into the environment in lethal concentrations. Moreover, with the increased sophistication of chemical and engineering science, many new substances not found in nature have been developed that are capable of causing unpredictable effects. Without proper management and disposal, the wastes from these substances can pose a threat to the environment and to living organisms.

Often the terms hazardous waste and toxic waste are used synonymously. However, the Resource Conservation and Recovery Act of 1976 defines a hazardous waste as material that may cause or significantly contribute to serious illness or death or that poses a substantial threat to human health or the environment when improperly managed. Working from this definition, the EPA identifies a hazardous waste by testing it to determine if it possesses any one of the following four characteristics: ignitability, corrosivity, reactivity, or toxicity. Therefore toxic wastes represent a broad subcategory of hazardous wastes.[2]

Epstein and colleagues have grouped hazardous wastes into the six major categories shown in Table 1.[1] (p. 14-26) Each type could easily be an essay topic of its own. For instance, the controversy surrounding radioactive waste disposal makes it a very complex topic. However, my aim in this essay is to give an overview of the hazardous-waste issue as a whole, without focusing on problems peculiar to a certain type of waste.

Environmental Consequences

Hazardous wastes pose a complex environmental problem because they directly affect the air, water, and soil while indirectly affecting living organisms. The environmental facet of this problem is very large. While we can only touch on some of the problems in this essay, the EPA provides an excellent description of the effect hazardous wastes have on all parts of the environment, including our rivers, lakes, and oceans.[3]

Air pollution has been a major environmental concern for several decades. Airborne toxicants are emitted into the atmosphere by industrial and manufacturing processes, sewage treatment plants, incinerators, and motor vehicles. For example, the burning of fossil fuels, such as coal or oil, increases the acidity in the atmosphere. These atmospheric emissions are causing a change in the chemistry of rain, a problem known as acid rain, discussed in an earlier essay.[4]

Another area affected by waste disposal is the underground water supply known as groundwater, a major source of water for drinking, agricultural, and industrial purposes. The EPA reports that nearly one-third of large, public groundwater systems in the US are showing signs of chemical contamination. The source of this contamination varies, but a major villain is the landfill, the cheapest and most dangerous form of waste disposal. Landfills are shallow trenches dug in soils of varying porosity where raw wastes or drums of wastes that eventually leak are dumped. There are approximately 93,000 landfills in the US.[3] (p. 48)

When waste materials are buried, rainwater percolates through the landfill, flushing out toxic chemicals to produce a polluted liquid called *leachate*. Leachate can leak from an insecure landfill to contaminate surface and groundwater supplies. Septic systems, improperly used pesticides and fertilizers, and leaking underground storage tanks also threaten groundwater sources, throwing contaminants such as trichloroethylene, benzene, gasoline,

Table 1: Major types of hazardous wastes.

	Description	Examples
Acids and Bases	Reactive materials that may be explosive, form a dangerous mixture with water, undergo a spontaneous chemical change to form a toxic product, or be corrosive.	Base: quick lime Acids: sulfuric, nitric, hydrochloric
Asbestos	Minerals composed of calcium or magnesium silicates formed into long thread-like fibers highly resistant to degradation.	Found in insulation of electrical wiring, hot pipes, furnaces; automobile brake linings; firemen's suits
Flammables	Chemicals that react strongly with oxygen in the atmosphere to produce intense heat that may lead to fire.	Petroleum, natural gas by-products
Heavy Metals	Raw materials used in technical processes. Traditionally the major component of hazardous wastes.	Lead, arsenic, zinc, cadmium, copper, mercury, selenium, beryllium
Radioactives	Unstable elements that emit charged particles potentially dangerous to living tissues. Classified by type of radiation emitted: gamma, neutron, beta, or alpha emitters.	Radium, thorium, uranium, plutonium
Synthetic Organic Chemicals	Industrial products manufactured from coal, natural gas, or petroleum. The basic units of these materials are hydrocarbons, which can be strung together to form complex molecules.	Rayon, nylon, industrial solvents, plastics, insulation foam, DDT, polychlorinated biphenyls (PCBs), dioxin

and disease-causing organisms into potential drinking water.[3] (p. 48)

The magnitude of ocean disposal is also quickly becoming a concern to scientists. The US, France, and the UK lead all other countries in disposing of dredged material, industrial wastes, and sewage sludge into the ocean. In 1978 an estimated 231 x 10^6 metric tons of wastes were legally dumped into the oceans worldwide. Already very small quantities of wastes from materials that have only been in use in the last 40 years, such as DDT and radioactive fallout, have been detected in the deepest regions of the oceans.[5]

Health Consequences

Health problems are often reported by residents living near areas where the air, water, or soil is known to be contaminated, directing attention to the serious dangers related to hazardous-waste exposure. Richard B. Kurzel and Curtis L. Cetrulo, Tufts University School of Medicine, Boston, Massachusetts, state that a number of laboratory tests on animals have shown that certain hazardous wastes, including dioxin and polychlorinated biphenyls (PCBs), may cause a variety of harmful effects to living organisms, such as cancer, reduced resistance to infectious disease, birth defects, and reproductive, gastric, and liver disorders.[6]

These toxic effects have been determined in laboratory tests under tightly controlled conditions. Unfortunately, epidemiologic investigations—statistical assessments of the incidence and cause of disease in certain populations—to find a correlation between toxic exposure and health effects are difficult. Clark W. Heath, Department of Community Health, Emory University School of Medicine, Atlanta, Georgia, states that the extent of a toxic-waste problem is hard to quantify because it is difficult to objectively measure the extent of exposure to toxic chemicals. Generally assessing exposure through tissue measurements of chemicals is ineffectual because many chemicals are nonpersistent in biologic systems. A general indicator of exposure is needed that doesn't rely on chemical analysis. Heath suggests that studying the frequency of chromosome breakage, slowed nerve conductive velocity, and sperm alterations may be viable alternatives for studying small populations.[7]

While determining the extent of chemical exposure is difficult, it is even harder to relate exposure to health effects. Amanda M. Phillips and Ellen K. Silbergeld, Toxic Chemicals Program, Environmental Defense Fund, Washington, DC, note that, as yet, relatively few studies have been successful in investigating this problem. Most of these health studies are limited, employing designs inappropriate to the site conditions. In addition, most are scientifically inadequate because of the small populations studied.[8] Phillips and Silbergeld believe that these studies, due to their limitations, often present a distorted picture of the health status in exposed groups.

A prime example is the highly controversial 1980 study of chromosome damage among residents of Love Canal in Niagara Falls, New York.[9] Love Canal is a residential area that had previously been the dumping ground for over 40 million pounds of industrial chemical wastes by Hooker Chemical Company. Residents were complaining of a variety of illnesses that they felt were caused by chemical exposure. The chromosome study was commissioned by the EPA to try to verify scientifically if chromosome changes could be detected in the Love Canal population. The study concluded that Love Canal residents may have damaged chromosomes and may have a high risk of developing cancer or having children with birth defects. This study confirmed the worst suspicions of the residents and naturally produced widespread panic.[10]

However when the EPA study was reviewed by other scientists, its validity became controversial. While cytogeneticist Margery W. Shaw, Medical Genetics Center, University of Texas Health Science Center, Houston, confirmed the study's results,[11] Sheldon Wolff, Laboratory of Radiobiology and Environmental Health, University of California, San Francisco, found the study to have a variety of technical problems including the lack of suitable controls. Wolff claims that this omission automatically makes the study's results meaningless.[12]

To resolve the controversy surrounding the EPA study, a team led by Heath conducted a carefully controlled cytogenetic analysis on 46 residents of the area surrounding Love Canal. Unlike the earlier EPA study, Heath and colleagues found that the frequency of chromosomal aberration did not differ significantly from control levels. However, the interpretation of these findings is limited by the sample size and by the problem of defining exposure. In addition, while chromosome alterations do persist in cells for many years following exposure to ionizing radiation, persistence is less likely when exposure is to chemicals. Therefore Heath and colleagues conclude that "although the presence of an increase in chromosome alterations could indicate acute exposure to chemical agents that cause chromosome damage, the absence of an increase does not establish the absence of such exposure."[13]

Besides chromosome studies, experiments testing other health effects are also subject to experimental design problems. Few studies have been able to determine conclusively a positive correlation between toxic exposure and health problems. In those studies that do find a correlation, researchers are careful to point out methodological difficulties and warn that further research will be required to substantiate the results.

One such study tested children exposed during gestation to the Love Canal neighborhood. Lynn R. Goldman, Bruce

Table 2: Selected list of organizations that are concerned with hazardous waste.

Academy of Hazard Control Management 5010A Nicholson Lane Rockville, MD 20852	Hazardous Materials Advisory Council 1012 14th Street, NW Suite 907 Washington, DC 20005
Air Pollution Control Association P.O. Box 2861 Pittsburgh, PA 15230	Hazardous Waste Treatment Council 1919 Pennsylvania Avenue, NW Suite 300 Washington, DC 20006
Association of State and Territorial Solid Waste Management Officials 444 N. Capitol Street, NW Suite 343 Washington, DC 20001	International Register of Potentially Toxic Chemicals Palais des Nations CH-1211 Geneva Switzerland
Citizen's Clearinghouse for Hazardous Wastes P.O. Box 926 Arlington, VA 22216	National Environmental Engineering Research Institute Nehru Marg, Nagpur 440020 India
Environmental Defense Fund 444 Park Avenue, S New York, NY 10016	United States Environmental Protection Agency Office of Public Affairs Waterside Mall 401 M Street, SW Washington, DC 20460
European Chemical Industry Ecology and Toxicology Centre Avenue Louise 250 (Bte 63) B-1050 Brussels, Belgium	

Lyon Memorial Research Laboratory, Children's Hospital Medical Center, Oakland, California, and colleagues found an increase in the number of low-birth-weight babies compared with the control children. The authors warn that the apparent association between low birth weight and hazardous-waste exposure should be confirmed in other studies before inferring causality.[14]

Designing experiments, defining potential risk indicators, and recognizing the limitations when interpreting data are just some of the problems preventing scientists from accurately assessing the risk posed by hazardous wastes. But until these problems are resolved, it would be dangerous to assume that there are no risks simply because we have not found a way to measure them.

Hazardous-Waste Legislation

While the public has demanded that the hazardous-waste problem be solved, many industries are resisting policy changes that may adversely affect their businesses. To counter industry's resistance, many organizations have emerged to promote safe waste disposal, and some of these are listed in Table 2. In the US and elsewhere, governments have the monumental job of resolving these conflicting interests by developing effective and fair legislation.

Stephen W. Kahane and colleagues, Jacobs Engineering Group, Pasadena, California, note that the federal government has developed over 30 statutes addressing environmental protection and pollution control.[15] Perhaps the most significant piece of legislation affecting hazardous-waste management is the Resource Conservation and Recovery Act (RCRA) of 1976, which defines hazardous waste, as we mentioned earlier. The RCRA also authorizes a comprehensive federal safety program that tracks the treatment, storage, and transport of hazardous wastes from the point of generation to final disposal.[2]

The RCRA bans certain wastes from land disposal and requires the EPA to develop an evaluation program to identify additional wastes that need to be restricted from land disposal. All waste producers are required to certify that they have established programs to reduce the amount and toxicity of wastes being generated. While not specifically prohibiting any type of treatment or disposal technology, the RCRA imposes just enough restrictions on land-based management methods (such as landfills) to make these alternatives less attractive financially than in past years. These restrictions are designed to encourage high-technology treatment alternatives, a topic that will be discussed in Part 2 of this essay.

While the RCRA was established to deal with current disposal practices, in 1980 Congress enacted the Comprehensive Environmental Response, Compensation, and Liability Act, nicknamed *Superfund*, to ameliorate the damage caused by abandoned hazardous-waste sites that threaten health or the environment. Superfund was initially established as a five-year, $1.6-billion bill fueled by taxes on oil and chemical production.[16] It established a National Priorities List (NPL) of sites that need immediate action. To date over 800 sites have been included in this list.[17]

A major emphasis of this bill is to hold companies liable for damages resulting from past waste-management practices. Liability may be imposed even if past actions were legal at the time. Consequently, generators, transporters, and disposers are responsible for cleanup costs incurred at sites and for damages to natural resources.

William D. Ruckelshaus, former administrator, EPA, Washington, DC, concedes that, when the Superfund bill was first passed, the complexity of the hazardous-waste problem was not entirely understood. Subsequently, the $1.6-billion budget proved to be wholly inadequate to deal with the problem.[18] Indeed, at the end of five years, the EPA had used up all of its funds but had only partially cleaned up six of the NPL sites.

Many of Superfund's troubles stem from unrealistic estimates of how quickly the problem could be addressed. For instance, the initial studies to determine what chemicals are present at a site can take up to 18 months to complete, at a cost of up to $800,000. In addition, the federal plan to clean up dumps by transporting wastes to safe and regulated sites has proven disastrous. Many of the new dumps have developed into dangerous sites themselves, further compounding the problem. Philip H. Abelson, deputy editor, *Science*, notes in a recent editorial that "there has been little net destruction of the waste and hence little in the way of permanent solutions to a set of nasty problems."[19]

The federal tax providing the money for Superfund expired September 30, 1985. Congress is currently struggling to renew the bill, but the House and Senate cannot agree on how large the new fund should be or how to raise the money.

Conclusion

Increased industrial production since World War II, the development of new chemicals not found in nature, and an increased population are only a few of the factors that have caused hazardous wastes to become a pressing issue to governments, industries, and the public. With over eight billion tons of waste disposed of improperly each year in the US alone, hazardous wastes may become the single most significant health and environmental issue of this century.

In Part 2, we will discuss waste-disposal technologies and how other countries deal with the hazardous-waste problem.

* * * * *

My thanks to C.J. Fiscus and Lisa Holland for their help in the preparation of this essay.

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