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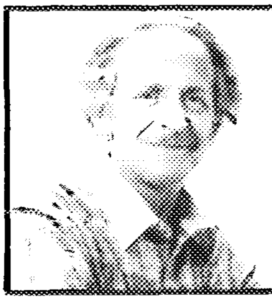

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Hazardous Waste. Part 2. A Problem That Cannot Be Buried

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The problems associated with hazardous waste extend beyond health and environmental consequences to include public policy, economics, and engineering. My intent is to provide an overview of some of these wide-ranging issues. In Part 1 we discussed the types of hazardous waste and described some of their adverse health and environmental effects. We also described the US legislation developed to deal with dangerous waste-disposal practices such as landfills, the primary type of waste disposal in the US.[1] In Part 2 we discuss alternative methods to land disposal for handling waste, including programs used by other countries. We also review the core literature and research fronts on hazardous-waste research.

Generators of hazardous waste face a moral and financial dilemma each time they choose a waste-disposal option. They often must choose between the safest option and the one that is less expensive but may be more likely to pose a threat to health or the environment. Generally it is more beneficial for a waste generator to choose the most inexpensive disposal option in order to keep a competitive edge.

Today the cheapest and simplest disposal option is land disposal. The US Office of Technology Assessment estimates that over 80 percent of hazardous wastes are being placed in or on the land, via landfills, surface impoundments, or underground injection wells.[2] (p. 15) However, in a 1982 study of New Jersey landfills, Peter Montague, Department of Chemical Engineering, Princeton University, New Jersey, concluded that all landfills, regardless of the type of containment and liner system used, will eventually leak.[3] It is becoming increasingly apparent that alternative technologies must be implemented for safe and effective disposal.

Alternative Treatment Options

Jay A. Mackie, director of process engineering, CH2M Hill, Corvallis, Oregon, and Kathleen Niesen, environmental project manager, CH2M Hill, Bellevue, Washington, divide the primary alternative treatment technologies into five categories.[4] **Physical treatment** alters the hazardous material to a more convenient form for further processing or disposal. **Chemical treatment** uses chemical reactions to alter hazardous constituents. This may include destroying the material or converting it to a more convenient form. A third process using **biological treatment** places microorganisms in contact with waste material to decompose the organic compounds in the waste. For instance, the organic materials found in landfills are decomposed by microbiological action. This process can be optimized by controlling the oxygen level, adding nutrients, or adjusting the concentration of microorganisms.

Thermal treatment utilizes high temperatures with excess or reduced oxygen to destroy waste material. A fifth type of treatment involves **fixation and encapsulation**, processes that remove water from a substance to form a solid mass containing a waste not easily transported by liquid.[4]

While Mackie and Niesen recognize the need for implementing alternative treatment options, they emphasize that even the most sophisticated disposal techniques still produce residues of some sort. Therefore, although the burden on land disposal can be substantially reduced, it cannot be eliminated entirely.[4]

A new and exciting area of biological treatment is the development of microbes that can break down specific hazardous waste. Gene splicing, selective breeding, and plasmid transfer are some of the methods currently being used to develop microorganisms that can "feed" on hazardous waste. D. Ghosal and colleagues, Department of Microbiology and Immunology, University of Illinois Health Sciences Center, Chicago, note that certain genetically modified species of *Pseudomonas* bacteria can detoxify halogenated compounds. These microbes can cleave a halogen moiety, such as chlorine, from the rest of a molecule at specific positions, rendering the compound harmless. Ghosal and colleagues have developed a *Pseudomonas* strain that can degrade 2,4,5-trichlorophenoxyacetic acid, the major acid component of Agent Orange.[5]

While these microbes sound like a promising solution, genetic engineering for pollution control is proceeding at a slow rate. Scientists and government regulators recognize that few technologies have been introduced into the environment without untoward effects. Caution is required because tests have not indicated if engineered organisms pose a hazard of their own when released.

A currently controversial research area focuses on finding safe methods for the disposal of radioactive waste. An excellent discussion of this topic is provided in *Management of Radioactive Materials and Wastes: Issues and Progress*, a book edited by Shyamal K. Majumdar, professor of biology, Lafayette College, Easton, Pennsylvania, and E. Willard Miller, professor of geography, Pennsylvania State University, University Park.[6]

One option is proposed by physicist Bernard Cohen, University of Pittsburgh, who recommends that nuclear waste be converted into a glass and then dumped into the ocean. Using this method, Cohen has calculated that the waste produced by one power plant in one year would eventually cause an average total of 0.6 fatalities, spread out over millions of years. He also calculated that the average dose of radioactive waste from ocean dumping will have no adverse ecological consequences.[7] It should hardly be a surprise that this proposal is highly controversial. John Warren Kindt, Department of Business Administration, University of Illinois, Champaign, notes that opponents of Cohen's viewpoint contend that the ocean has only a limited capacity to accept wastes before detrimental environmental problems arise.[8]

How Other Countries Cope

Hazardous wastes are hardly unique to the US. Bruce Piasecki, professor of environmental history, Center for Liberal Studies, Clarkson University, Potsdam, New York, and environmental attorney Gary A. Davis, Knoxville, Tennessee, note that European nations have their share of problems. For instance, 268 Dutch families were evacuated in 1980 from a housing development built above a chemical-waste dump in The Netherlands. However, some European countries are way ahead of the US in legislating and implementing alternative technology systems designed to reduce the amount of toxic waste generated, thereby minimizing land disposal.[9]

For example, Denmark is considered a leader in waste management. Its Kommunekemi, or "community chemical" plant, is run by a government-owned waste-management firm that also profits from consulting with other countries. The Danish system includes a network of 21 chemical-waste collection and transfer stations situated throughout the country that are owned and operated by the municipalities in which they are located. Danes dispose of poisonous household chemicals at 275 drop-off stations that are in turn linked to the transfer stations. About 60,000 tons of used oil and chemical wastes from the transfer stations are fed into the Kommunekemi plant for detoxification and incineration.[9]

In Hesse, Federal Republic of Germany (FRG), the Hessigchen Industriemull (HIM) has been developed to manage chemical wastes. Alois Scharsach, Environmental Engineering Division, Von Roll Ltd., Zurich, Switzerland, states that the HIM system is designed to handle about 55,000 tons of organic wastes, including intermediate storage and final disposal, through thermal treatment. The HIM incinerator uses a novel scrubbing system that cleans the exhaust gases with a liquid that rapidly evaporates, leaving a dry, easily managed powder. This treatment facility is heavily subsidized and stringently regulated by the state on the theory that this will ensure quality waste control.[10]

Piasecki and Davis note that the success of these alternative technologies in Europe makes the US preoccupation with land disposal seem misguided. They state that "Washington's emphasis on securing toxic landfills for future dumping appears profoundly inconsistent with our longstanding leadership in technology."[9]

While other nations, including Sweden, Finland, and The Netherlands have followed the early lead of Denmark and FRG, many countries are still struggling to cope with the waste problem. In Poland, Eugeniusz Pudlis, Warsaw correspondent for *AMBIO*, reports that smelting works produce about 98 percent of all of Poland's hazardous wastes. Not surprisingly, heavy metals in locally grown vegetables are from 30 to 70 percent higher than the norms set by the World Health Organization. While Poland's dangerous waste problem is recognized by the Western world, Pudlis states that Polish political authorities have discouraged publications describing their hazardous-waste problems or any cleanup plans they may be developing.[11]

Many industrial plants have been installed in Third World countries by more technologically advanced countries. This poses problems for these struggling countries, since technology is being introduced into societies that are not prepared to deal with the consequences, such as the production of hazardous waste. As discussed in the proceedings of the public hearing entitled *The Human Environment: Action or Disaster?*, sponsored in part by the United Nations Environment Programme and the World Wildlife Fund in the United Kingdom, Third World legislation does not address the problems of waste disposal. Therefore Western industrialists are able to set up factories with lax safety precautions that would be banned in their own countries. Controversy arises over who should take responsibility for the consequences of industrialization: the Third World host or the manufacturer.[12]

European Legislation

Safe management of hazardous waste involves more than sophisticated technology. European governments recognize the need for effective public policies to introduce and use these technologies rationally. For instance, instead of each nation developing its own framework for regulating chemical hazards, they jointly developed a uniform approach for all European nations. In 1982 the European Community adopted the "Directive on the Major Accident—Hazards of Certain Industrial Activities," commonly known as the Seveso Directive. The goals of this directive are to prevent major accidents caused by industrial activities and to limit the effects on workers and the surrounding environment in the case of such accidents.[13]

This prevention-oriented approach is in direct contrast to the current response-oriented US legislation, which calls for after-the-fact remedial efforts. US legislators could learn from the Seveso Directive, which shows that a uniform approach is more effective than the current US situation of having different hazardous-waste laws in each state. Often these disparate laws frustrate industries and suppliers because they must tailor plant operations to comply with the requirements peculiar to each state, an expensive and time-consuming process.[13]

However, according to Bernard Dixon, British science writer and consultant, some countries feel that uniform standards may be inappropriate since environmental factors, such as prevailing winds, ocean currents, and soil types vary geographically. Dixon notes that in the UK, legislators feel that decisions controlling hazardous wastes should be based on the capacity of a particular environment to handle specific types of pollutants.[14]

Obstacles

Many obstacles are preventing the US from developing successful alternative hazardous-waste management systems. One major problem, according to Linda E. Greer, Environmental Defense Fund, Washington, DC, is that the official Environmental Protection Agency (EPA) definition of hazardous waste is incomplete. For instance, the EPA's hazardous characteristics are so narrowly defined that many dangerous wastes are not listed as hazardous. Consequently the US is operating under a seriously flawed regulatory system that does not monitor many wastes that pose a threat to health and the environment. Greer cites dioxin as a prime example of a dangerous chemical that is not currently a regulated hazardous waste.[15]

Another obstacle to implementing high-technology options is the siting of hazardous-waste facilities. Residents near proposed sites usually are concerned about the waste characteristics; the management methods; the location of the facility in relation to the population, groundwater, and sensitive environmental areas; and the planned mitigation methods for reversing any negative impacts. Often, the controversies surrounding waste facilities cause residents to adopt a "not in my backyard" attitude toward these facilities.

Risk assessment can play a useful role in providing information that may appease some of the concerns of the residents living near a proposed site. It can help establish regulatory standards, set priorities for research and development, identify risk levels associated with treatment and disposal options, and determine appropriate locations for a facility. I discussed how risk assessment of toxic substances in the environment is evaluated in an earlier essay.[16]

The Office of Technology Assessment (OTA) states that risk assessment is often calculated using mathematical models to extrapolate from the high doses of toxic material tested in laboratory situations to the usually lower doses detected in the environment. The OTA warns, however, that individual assessments generated by different models vary considerably, posing a limitation in using risk estimations in the decision-making framework.[2] (p.18)

Joseph V. Rodricks, Environ Corporation, Washington, DC, notes that in

Table 1: Selected *SCI®/SSCI®* research fronts on hazardous waste. A=number. The first two numbers indicate the year of the research front. B=name. C=number of core items. D=number of published items for the year indicated.

A	B	C	D
85-0453	Polychlorinated biphenyls in the environment	18	136
85-0497	Determination and biodegradation of polychlorinated dibenzofurans and polychlorinated dibenzodioxins in the environment	32	199
85-1035	Clinical effects of exposure to lead, mercury, and other toxins	2	17
85-1853	Toxic and other effects of PCBs and other chemicals	2	16
85-1998	Studies of economic optimization in pollution regulation	3	25
85-3130	Sorption, bioconcentration, toxicity, and diffusion of pollutants in water and sediments	29	350
85-4120	Radioactive-waste immobilization by microstructural modification	2	15
85-4949	Cultural, technological, and environmental dangers and the risk of cancer	2	15
85-5469	Managing risk, risk assessment, analysis, and perception in environmental, health, and other hazards	5	38
85-7316	Health effects in populations exposed to chemicals from waste disposal sites	2	17

risk validation there are limitations in the use of epidemiological and clinical data for identifying the toxic properties of chemical substances.[17] In addition, as discussed in Part 1, determining the effects of a toxic substance on the environment is very difficult.[1] For these reasons, the OTA recommends that risk assessment be used only as an analytical tool and not as a final means for making decisions.[2] (p.18)

Hazardous waste also poses an economic problem. Nobel Prize-winning economist Wassily Leontief, University Professor, New York University, developed a model that calculates the costs of eliminating pollution. The model also examines the effects of pollution elimination on the prices of the goods that produce polluting by-products.[18] We will discuss the work of Leontief in an upcoming essay. Another Nobel laureate, Sir Richard Stone, the emeritus Leake Professor of Finance and Accounting, Cambridge University, UK, extended Leontief's analysis. He studied the consequences of alternative methods of charging for pollution elimination and questioned how far elimination should be taken.[19] Stone's other economic contributions have been discussed earlier.[20]

Research-Front Data

As we have discussed, the problem of hazardous waste is a significant issue. Yet there are very few research fronts devoted strictly to this topic. The few research fronts listed in Table 1 reflect some of the varied aspects of the waste issue. The fronts cover research fields from toxicology and engineering technology to risk analysis and the economics of pollution.

Not surprisingly, the journals covering hazardous-waste issues are also multidisciplinary. Table 2 is a selected list of journals containing articles on some aspect of hazardous waste. This list was developed using both quantitative and subjective criteria. Many journals publishing the core and citing articles in the hazardous-waste research fronts are included in the list, and the *Journal Citation Reports®* was also examined for titles. In addition, the journals suggested by subject specialists and reviewers were added.

Usually our research fronts are able to pinpoint the hot areas of research. However in this case, our data reveal that hazardous-waste research lacks a focal point, or hot area of study. The fact that this is a relatively recent research field may in part account for this. Perhaps as this area picks up momentum, scientists will be able to effectively tie the findings from various fields together. This may then be reflected in research fronts more directly related to hazardous waste.

One of the larger areas of study deals with the effects of chemicals, such as

Table 2: Selected list of journals reporting on various aspects of hazardous waste. A = title, first year of publication, and publisher. B = 1984 impact factor.

A	B
AMBIO (1972) (Royal Swedish Academy of Sciences) Pergamon Press, Elmsford, NY	0.65
Chemosphere (1972) Pergamon Press, Elmsford, NY	1.12
Environment (1958) (Scientists' Institute for Public Information) Heldref Publications, Washington, DC	0.65
Environmental Health Perspectives (1972) National Institute of Environmental Health Sciences, Research Triangle Park, NC	1.50
Environmental Science & Technology (1967) American Chemical Society, Washington, DC	2.60
Harvard Environmental Law Review (1976) Harvard University Law School, Cambridge, MA	1.96
Hazardous Waste & Hazardous Materials (1984) (Hazardous Materials Control Research Institute) Mary Ann Liebert, New York, NY	NA
Journal of Environmental Engineering—ASCE (1956) American Society of Civil Engineers, New York, NY	1.01
Journal of Hazardous Materials (1975) Elsevier Science Publishers, Amsterdam, The Netherlands	0.54
Journal of the Air Pollution Control Association (1951) Air Pollution Control Association, Pittsburgh, PA	0.78
Journal of the Water Pollution Control Federation (1928) Water Pollution Control Federation, Washington, DC	0.98
Pollution Engineering (1969) (Institute of Hazardous Materials Management) Pudvan Publishing Co., Northbrook, IL	NA
Water Research (1967) (International Association on Water Pollution Research & Control) Pergamon Press, Elmsford, NY	1.38

polychlorinated biphenyls (PCBs), on living organisms and the environment. PCBs are among the most stable chemicals known. Therefore, when released into the environment, they degrade very slowly and become incorporated into the food chain, posing a danger to living organisms. There were more than 135 papers published on "Polychlorinated biphenyls in the environment" (#85-0453), with 18 core documents. The central core paper for this front, co-cited 25 times, is a paper by K. Ballschmiter and M. Zell, Department of Analytical Chemistry, Ulm University, FRG. High-resolution glass-capillary gas chromatography was used to identify and quantify single components in PCBs. This method provides a means for thorough analysis of PCBs in environmental samples.[21]

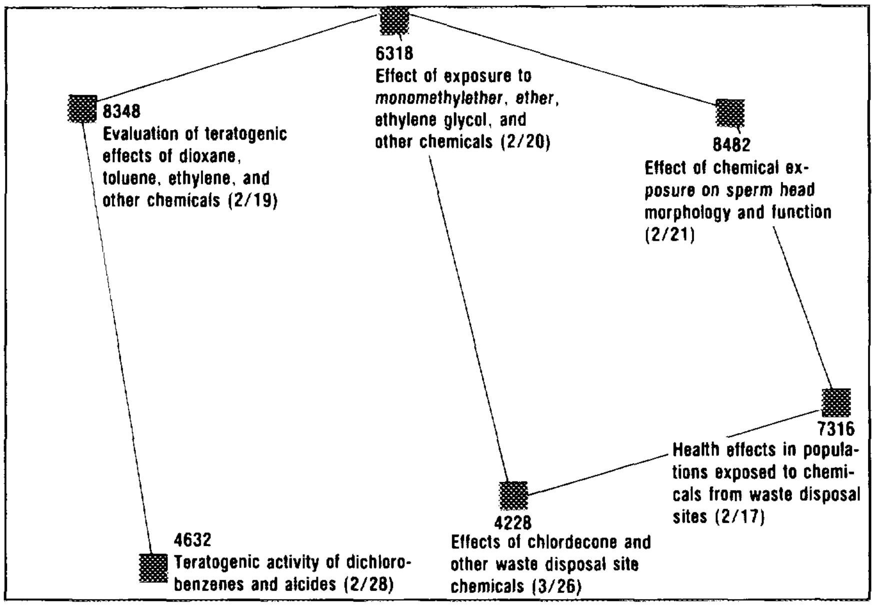
Figure 1 is a multidimensional-scaling map for the C2-level research front on "Health effects of chemical exposure" (#85-0540). This map shows how fronts focusing on various chemical effects are linked together by co-citations.

In another area related to hazardous waste, the research front on "Cultural, technological, and environmental dangers and the risk of cancer" (#85-4949) includes papers dealing with the sociological and statistical problems in public risk management of waste disposal. One of the two core documents for this topic is a book by anthropologist Mary Douglas, Northwestern University, Evanston, Illinois, and Aaron Wildavsky, Department of Political Science, University of California, Berkeley, that discusses the sociocultural impact of risk and disposal technology.[22]

The structural modification of radioactive waste, such as converting it into a glass, as discussed earlier, is the topic of the front on "Radioactive-waste immobilization by microstructural modification" (#85-4120). Kindt's article in *Natural Resources Journal* is 1 of the 15 citing articles.[8] One of the two core papers in this front, by A.E. Ringwood and colleagues, Australian National University, Canberra, compares the ability of different glasses to immobilize high-level nuclear waste.[23]

Much of the literature concerning hazardous waste is produced in the form of government reports, which may be cited but are not directly covered as

Figure 1: Multidimensional-scaling map for C2-level research front #85-0540, "Health effects of chemical exposure," showing links between C1-level research fronts. The number of core/citing items are given in parentheses following the research-front titles on the map.



source material in the *Science Citation Index*® (*SCI*®). We did an online literature search in both the National Technical Information Service (NTIS) and the Government Printing Office (GPO) databases to find the number of government documents published on hazardous waste. From July 1976 to April 1986, the GPO published over 300 documents generated by the legislative and executive branches of the federal government related to hazardous waste, including the OTA report, *Technologies and Management Strategies for Hazardous Waste Control*, mentioned earlier.[2] The EPA published about 90 of these papers on hazardous wastes.

Between 1964 and 1986, the NTIS published over 1,000 documents related to government-sponsored research, development, and engineering reports on hazardous waste. The NTIS includes reports from government agencies such as the US Department of Energy, Department of Defense, and National Aeronautics and Space Administration.

Conclusion

The late R. Buckminster Fuller likened planet Earth to a spaceship. Both are small, vulnerable, delicately balanced mechanisms with finite resources.[24] Today the fragile resources of Spaceship Earth are being threatened by hazardous waste. The changes required to deal with the past, present, and future problems of hazardous waste will demand a high degree of technological and political sophistication, as well as a fundamental shift in the way we think about the world and our place in it.

* * * * *

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