HAZARDOUS WASTE

ISSUES AND ANSWERS

AMERICAN INSTITUTE OF PROFESSIONAL GEOLOGISTS
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AIPG
COMPETENCE INTEGRITY ETHICS

Foreword

The American Institute of Professional Geologists is a nationwide organization of about 5,000 members representing all areas of specialization in the professional practice of geology. The Institute serves both the profession and the public through its certification program and its involvement in public affairs. One form of AIPG involvement in public concerns is publication of "issue papers" such as this one, dealing with current specific matters in which geology is significant to formulating prudent public policy, legislation, or governmental regulation.

The disposal of hazardous waste (toxic chemical waste) is currently a focus of public interest. Prudent public policy concerning disposal of hazardous waste requires a good understanding of the scientific, technical, and social issues involved. The purpose of this booklet is to provide policy-makers, legislators, and the general public with information to better understand the issues, particularly geological considerations.

We hope this booklet serves that purpose. If you have questions or comments, or if you would like additional copies, please contact:

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Geological material in this booklet was submitted by an AIPG ad hoc committee of experts on hazardous-waste disposal chaired by Benton M. Wilmoth and including Michael Arndt, Dick Benson, Mike Brazie, Ted Clark, Harry Crouse, Bill Cutcliffe, Paul DuMontelle, Herb Eagon, Serge Gonzales, John Hawley, Jeffrey Hynes, Dave Johe, Ron Landon, Albert M. La Sala, Jr., Harry LeGrand, Peter Lessing, Don Malone, John Mullen, Richard Proctor, Norm Tilford, and W.P. Wagner. The booklet was compiled from many sources by Fred Schroyer, science writer and editorial consultant.

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Important note—This booklet furnishes general information in the spirit of developing enlightened management policy. This material is introductory, and not intended to provide detailed information or professional advice. Because each situation is unique, this booklet cannot be used in solving specific problems. The direct advice of professionals in the discipline is essential. A Directory of Certified Professional Geologists, indicating their specialties and addresses, is available without charge from AIPG.

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Contents

Hazardous Waste—
A Big Problem Growing Bigger

What it is—Every human activity produces waste, but not all wastes are hazardous. Waste is hazardous if:

- It contains toxic chemicals
- It is a fire hazard
- It is corrosive or caustic
- It may explode
- It reacts violently with water or air
- It generates toxic gases
- It is biologically viral
- It is radioactive*

When improperly handled, such wastes may pollute our water, air, and land. People, animals, and plants may be in jeopardy of poisoning, burns, or genetic damage. But *hazardous wastes can be properly handled, using present technology and geological expertise.*

What the wastes are—Hazardous wastes are the byproducts of industry. Manufacturing of paint, paper, and pesticides generate flammable solvents or toxic chemicals. Refining of metals, electroplating, making medicines, and tanning leather produce caustics, corrosives, or poisonous chemicals. Textile mills, chemical plants, and oil refineries create toxic wastes. America the Industrial Giant is unavoidably America the Hazardous-Waste Generator.

The wastes are millions of tons of sludges, solvents, acids, PCBs, flotation tailings, shavings, wastewater, and on and on. Some of these materials have been produced for over a century; others are more recent products of our advanced chemical technology. Some have low toxicity, and others, such as the infamous dioxin, appear to be dangerous in even tiny amounts.

How much is generated? The U.S. Environmental Protection Agency (EPA) calculated that, in 1981, American industry generated 150 *million metric tons** of hazardous waste. Most was in liquid form, so this waste can also be expressed in liquid measure: 40 billion gallons.* To put this in perspective: if all 40 billion gallons were placed in standard 55-gallon drums, and they were laid end-to-end, they would form a line 400,000 miles long, which would encircle the Earth 16 times! It is indeed an intimidating quantity.

Hazardous wastes are generated not only by industry, but by consumers as well. For example, household trash may include drain cleaners, paint thinner, automotive fluids, and discarded medicines, all of which become mixed with nonhazardous wastes in landfills. Thus, volumes of hazardous waste cited here are only *producer* wastes, and do not include *consumer* wastes. Clearly, hazardous waste is a massive problem that affects virtually every industry and person in America.

It is heartening to note that the problem can be solved with existing technology and geological know-how. But major obstacles remain, including the public's understanding of both the problems and the solutions. This booklet's purpose is to improve public understanding.

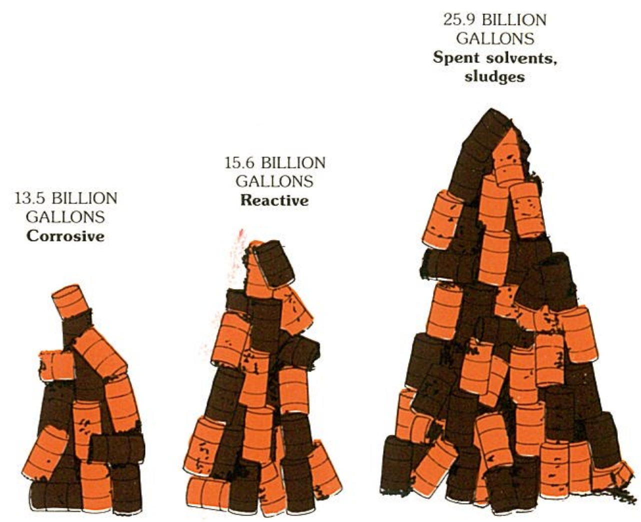
*Radioactive waste has unique problems which AIPG addresses in a separate report.

**A metric ton = 1,000 kilograms, or 2,204.6 pounds. See Glossary for conversion factors.

How Much?

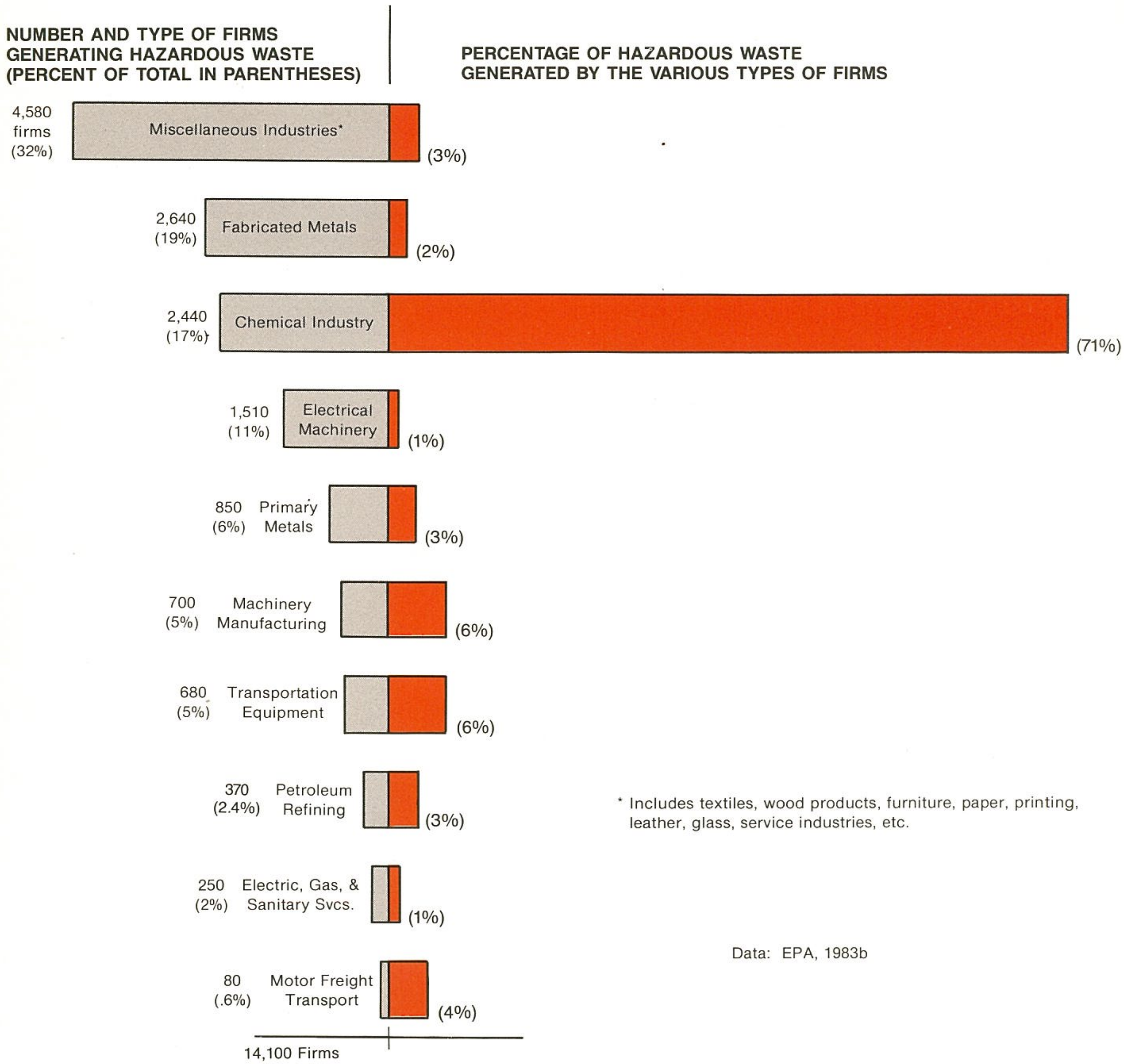
40 billion gallons generated in 1981. (Categories total higher due to overlap. For example, a solvent may also be reactive or corrosive.)

Data: EPA: 1983b



WHO GENERATES HOW MUCH?

14,100 firms made 40 billion gallons in 1981



* Includes textiles, wood products, furniture, paper, printing, leather, glass, service industries, etc.

Data: EPA, 1983b

EPA has identified 60,000 firms that potentially generate hazardous waste. They are large and small companies, representing all industries. But in a 1981 study, only 14,000 actually produced significant waste. One-sixth of the firms (the chemical industry) generates 71% of the waste; one-third of the firms (diverse, smaller industries) produced only 2.5%.

The Effects of Hazardous Waste

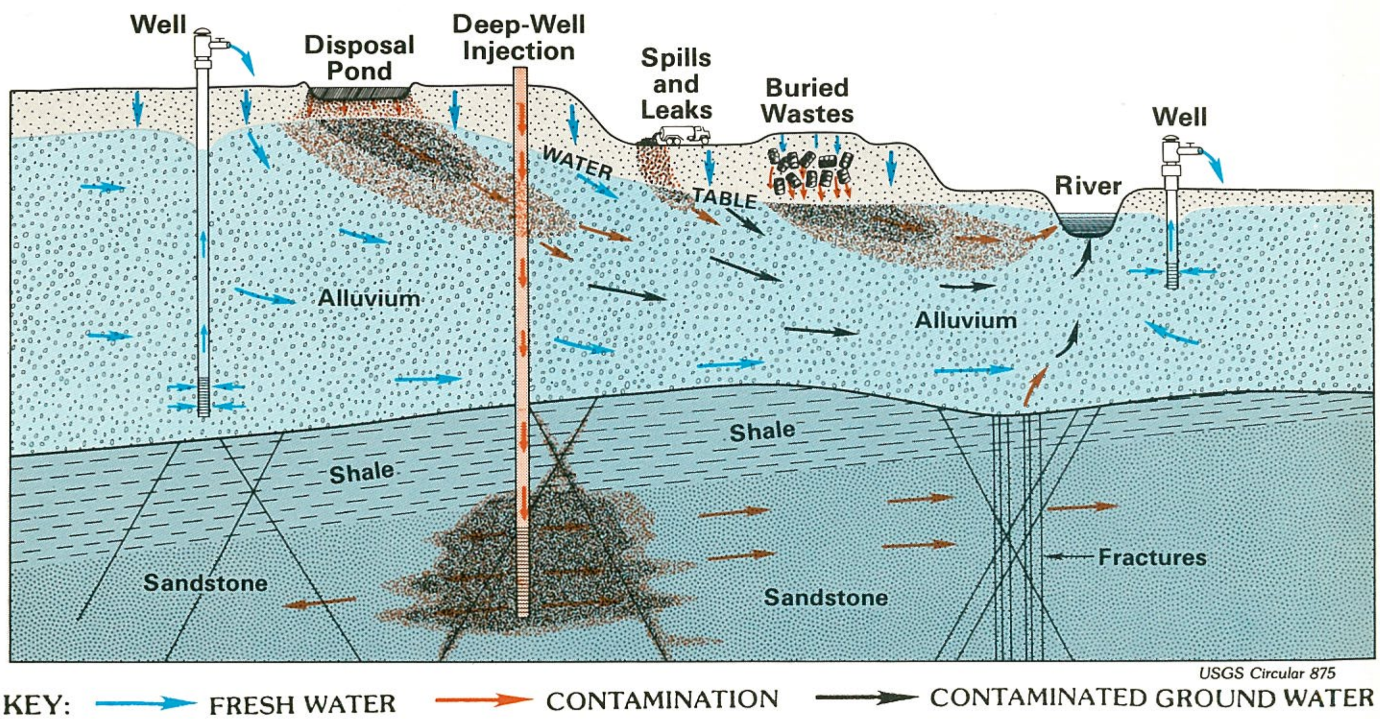
Until very recently, most hazardous waste was dumped or buried in landfills, with little regard for the geological stability of sites. Failure to understand the basic geologic and hydrologic principles illustrated on these pages has led to an array of problems.

- Hazardous wastes *leach into ground water* from improperly designed sites, contaminating the water for hundreds of years. (Ground water is the source of drinking water from municipal wells and private wells and springs—see illustrations.)
- Hazardous wastes also *leach into surface water*, contaminating streams, lakes, and affecting aquatic life, drinking water, and recreation.
- Hazardous wastes can cause *human, animal, and plant poisoning* ranging from flu-like symptoms and loss of hair, to death. These problems may appear years after exposure.
- Hazardous wastes can *contaminate soil*, making it unsuitable for agriculture.
- Hazardous wastes *depreciate land values.*
- Hazardous-waste *costs are vast*—to those that generate waste, to government regulators, and to the public.
- Hazardous waste, when improperly disposed of, *creates problems that may endure for generations.*
- The bitter experiences of Love Canal, Times Beach, and other sites have *created public distrust* of the agencies and industries involved, inhibiting expansion of waste-disposal facilities.

EPA estimates that perhaps 90% of hazardous waste from about 750,000 sources in the U.S. is disposed of improperly, leading to the problems listed above.

These problems often result from lack of geologic study prior to disposal at the site.

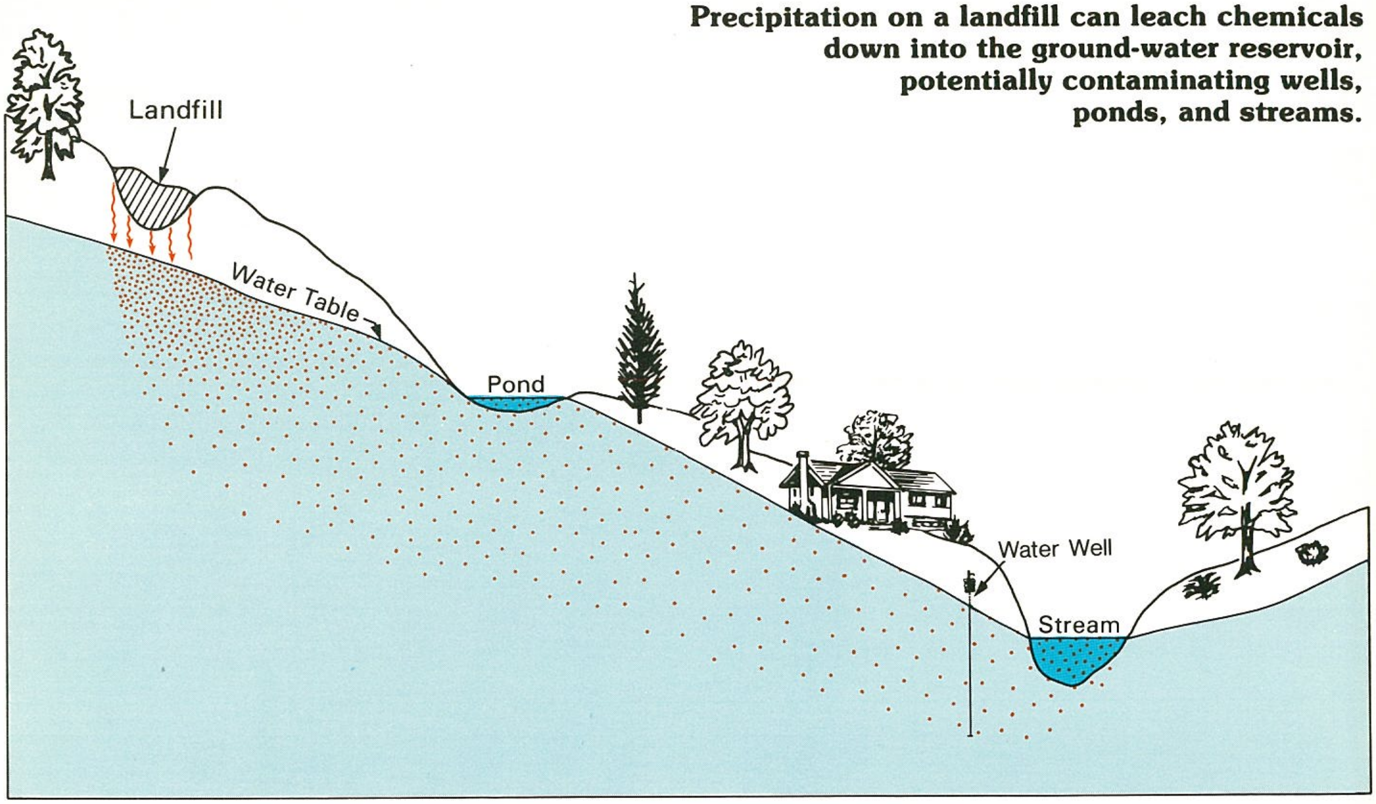
Industrial wastes are disposed of in many ways



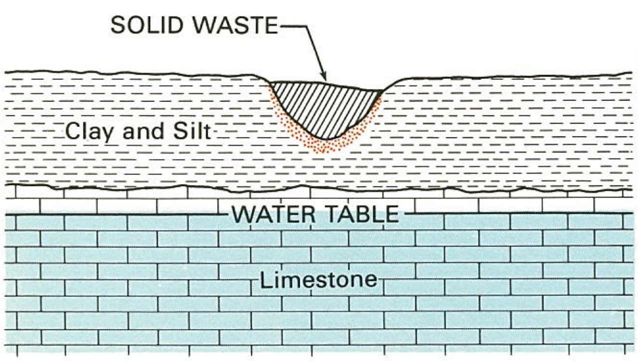
A vast array of industrial chemicals, including large volumes of liquid and solid toxic compounds, have been disposed of in seepage ponds and by shallow burial. By 1981 the inventory of toxic wastes was 6 billion cubic yards at 100,000 sites in the U.S. (Radioactive wastes are a special category of industrial wastes owing to their high toxicity. The amounts and number of sites are small.)

CONTAMINATION FROM LANDFILLS

Precipitation on a landfill can leach chemicals down into the ground-water reservoir, potentially contaminating wells, ponds, and streams.



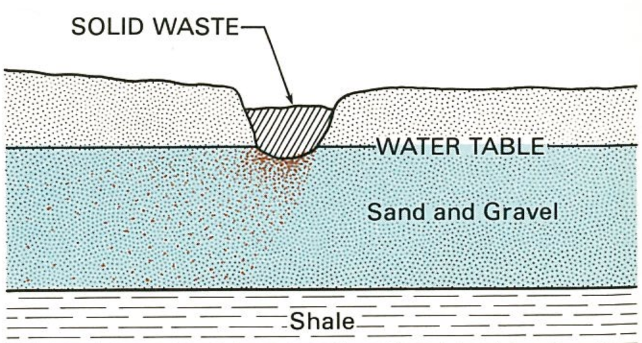
In the humid areas of the country, rain and snow on a landfill may carry dissolved substances downward, delivering pollutants to the ground water. The degree of hazard depends on the geology of the site, design of the landfill, and character of the wastes.



Relatively Safe

Pollutants move slowly in clay and silt and many noxious compounds are absorbed on clay-mineral grains.

The best of the pre-regulation landfills were like this, but today this one would not meet EPA's stringent specifications for hazardous waste.



Unsafe

Pollutants entrained directly in ground water.

(Illustrations from USGS Circular 601-F)

Where Hazardous Waste Is Found

Any hazardous waste can exist in five places:

1. Where it is generated
2. In storage, awaiting disposal
3. In transit to the disposal site, which may be on the site where it is generated, or many miles away
4. At disposal sites—for example, in barrels in a landfill.
5. In the most dangerous place: an unexpected location, due to leaching, spills, wind, earthquake, explosion, or human error.

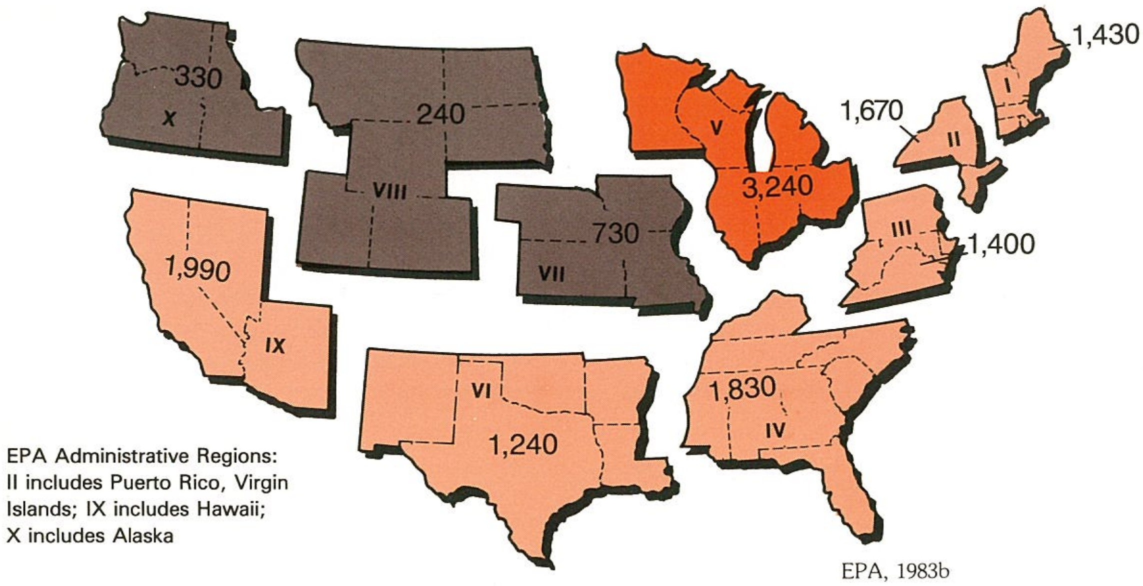
To cover all five, Federal regulations now control hazardous waste "from cradle to grave" and beyond—that is, from generation through proper disposal, with monitoring for leakage many years afterward.

Where are the generators? The heavily industrialized areas of the Nation are where hazardous wastes proliferate, as the map confirms. But all states have hazardous wastes that have been improperly buried, dumped, transported, and spilled. Hundreds of abandoned wastes sites have been found, located without regard to the geology of the area, and with no record of what substances may be in rusting drums. Unfortunately, these sites are frequently discovered only because adverse effects bring them to public attention. EPA has inventoried about 16,000 uncontrolled sites Nationwide.

Not here, you won't! Public distrust is the legacy of improper disposal over decades. The EPA says that public opposition to siting of hazardous-waste disposal facilities is the single greatest obstacle to properly managing the wastes. Public protest to date has closed some existing facilities, prevented improvements to others, and halted some in the planning stages.

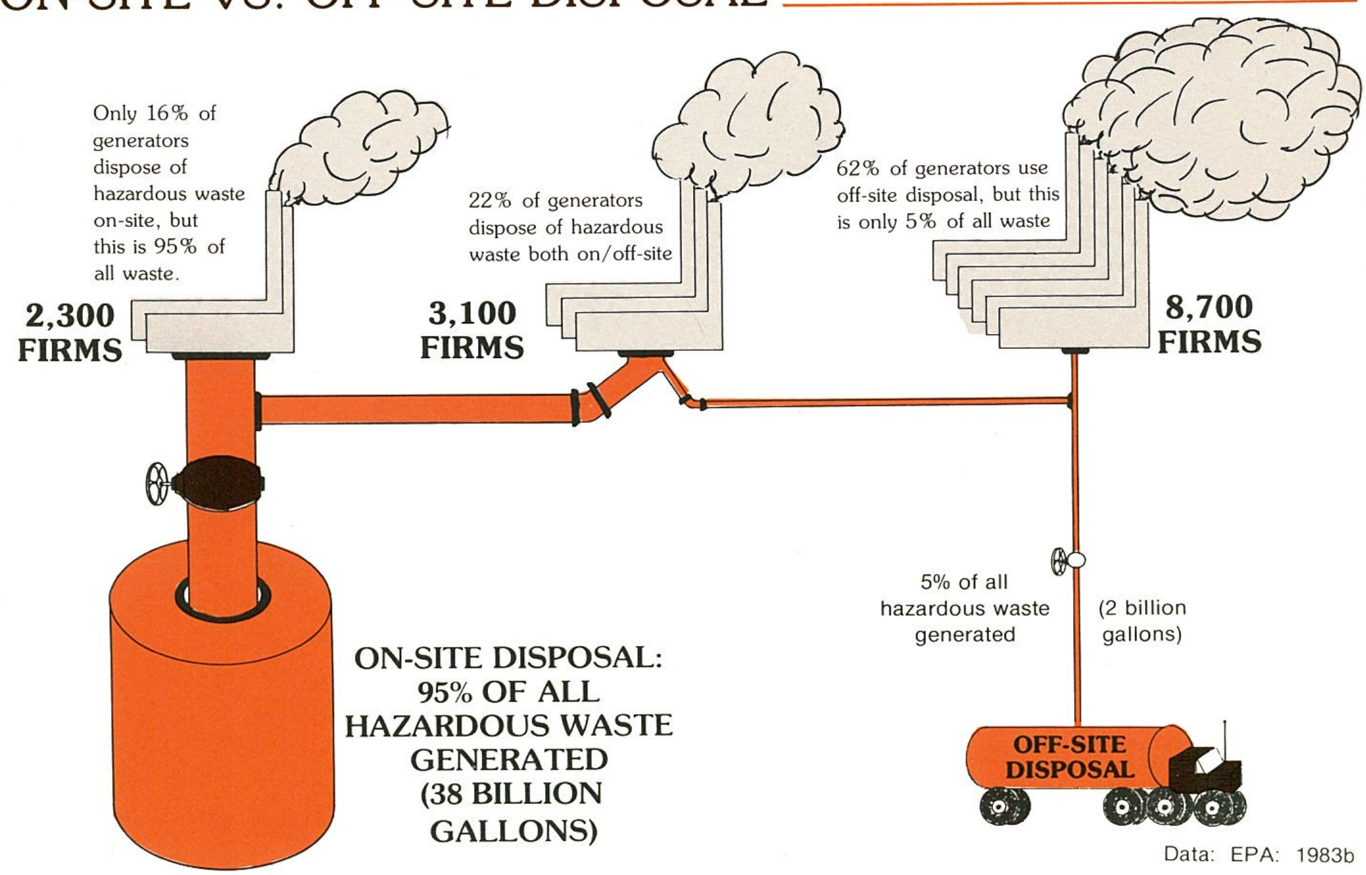
National Water Well Association

WHERE THE GENERATORS ARE



The 14,100 firms producing hazardous waste in 1981, by EPA administrative regions (I, II, etc.). The greatest concentration of firms is in the Great Lakes Region (3,240 firms).

ON-SITE VS. OFF-SITE DISPOSAL



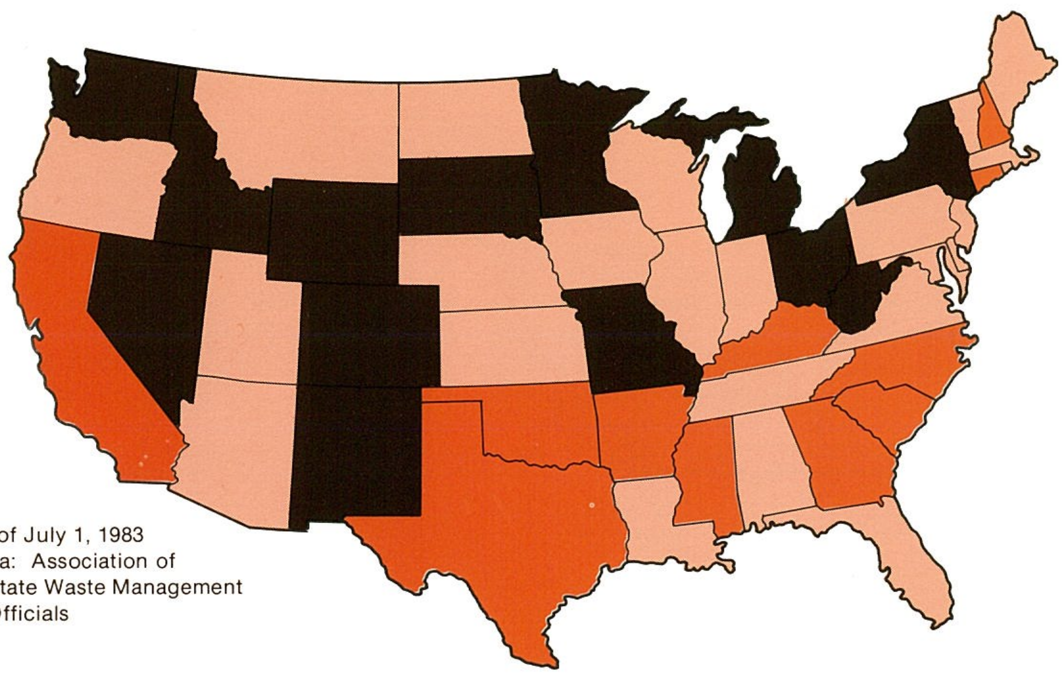
Regulating Present and Future Waste . . .

No single law covers all hazardous waste. Several laws collectively deal with the different types of waste. Of these, *RCRA, the Resource Conservation and Recovery Act of 1976,* is the closest thing to a comprehensive law protecting public health and the environment from hazardous waste. RCRA requires cradle-to-grave management of hazardous waste, including generation, transport, final disposal, and monitoring.* RCRA sets standards for hazardous-waste testing, labeling, storage, and packaging. It requires a *manifest* for all shipments, showing the nature and volume of wastes.

Under RCRA, EPA sets the regulations and enforces them. About one-third of EPA's 1983 budget was dedicated to enforcing hazardous-waste regulations. EPA encourages states to set up their own programs. As of mid-1983, 35 states had "Phase I" plans (standards for waste generators, transporters, and facilities; shipping manifests). Several states also had advanced "Phase II" plans (technical standards, facilities permits). For those states that do not set up their own plans, EPA develops a program (see map), but ultimately the states will run their own programs. EPA's goal is to have 100% of the Nation's hazardous-waste management facilities fully permitted by 1989.

*Exempt from the requirements are small-volume hazardous-waste generators—under one metric ton/month—whose waste often goes into sanitary landfills. There are about 700,000 of these firms, and they are 90% of the hazardous-waste generators. The small-volume-generator exemption is a serious deficiency of RCRA, but the exempt status is under study, and EPA has proposed rules that would regulate these generators.

WHO'S IN CHARGE?



As of July 1, 1983
Data: Association of State Waste Management Officials

In compliance with Resource Conservation and Recovery Act (RCRA):

- State has own hazardous-waste program, Phase II interim, advanced
- State has own hazardous-waste program, Phase I interim
- EPA set up state's program

. . . and Cleaning Up the Past

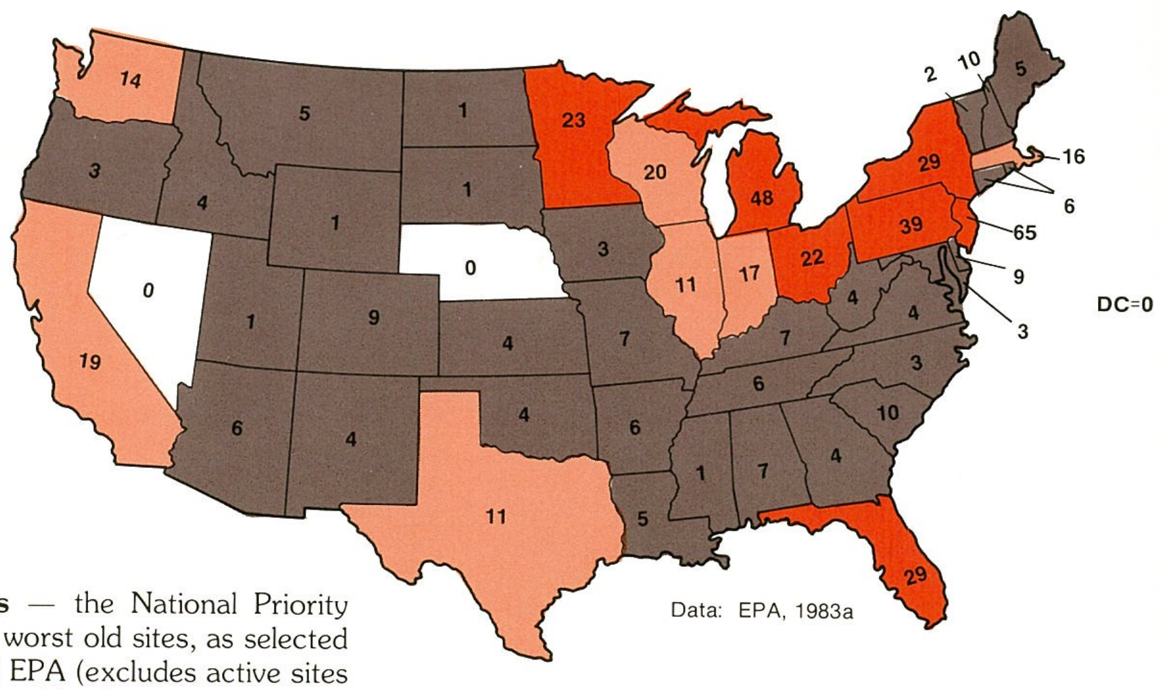
Superfund. RCRA covers day-to-day, routine hazardous-waste disposal, now and future. But what about yesterday's contaminated sites, now abandoned? And what about emergencies, such as chemical spills, oil spills, imminent fire or explosion, or imminent water contamination? *Superfund* (Comprehensive Environmental Response, Compensation, and Liability Act, CERCLA) was created in 1980 to cover both the past, and present emergencies. EPA manages Superfund, and is to collect $1.6 billion, mostly via a tax on the chemical and petroleum industries, and use it as needed by 1985. (This five-year period does not allow enough time for Nationwide cleanup, and an extension is possible.)

Superfund allows EPA to act immediately in cleaning up a spill or other emergency, and then to bill those responsible. For the perhaps 16,000 abandoned hazardous dumps, EPA has created the National Priority List. States nominate their worst sites for cleanup, EPA prioritizes them using its Hazardous Ranking System model, and the worst go onto the National Priority List (which in August 1983 included 406 sites—see map). EPA and the states then reach agreements on cleanup, under which states pay 10%* and Superfund pays the rest. Often, the responsible industries will voluntarily perform the cleanup at their own expense.

Specific questions about RCRA and Superfund regulations are answered by EPA on their Hot Line, 800/424-9346.

*10% for private sites; 50% for public sites.

SUPERFUND SITES



Superfund Sites — the National Priority List (NPL) of the worst old sites, as selected by the states and EPA (excludes active sites and those on Federal land).

The 546 sites include 406 on current NPL, 133 in a proposed update, and 7 pending. 75% of these sites have hazardous substances in ground water, 56% in surface water, and 20% in surrounding air.

- 21 - 65 sites
- 11 - 20 sites
- 1 - 10 sites
- State nominated no sites

Getting Rid of Hazardous Waste

How *do* you get rid of toxic, flammable, corrosive, or explosive waste? The basic plan is to generate as little as possible in the first place, recycle as much as possible, reduce the volume and toxicity, and dispose of the remaining waste safely. These approaches have evolved:

1. **Process Modification**—Change the manufacturing process to reduce up-front the quantity and toxicity of wastes. This goes to the heart of the problem. Although such changes require research and are expensive, they also reduce disposal cost. A complicating factor is that waste streams change over time, and even the effluent from continuous processes may vary.
2. **Resource Recovery, Recycling, and Waste Exchange**—Scrub the wastes and reuse them, or sell them for other purposes. Waste solvents might be burned to produce heat; waste sulfuric acid might be used to make batteries and phosphate fertilizer. Waste-exchange catalogs are available from government agencies, chambers of commerce, trade associations, and brokers, helping one industry's trash become another's resource. During 1981, 55% of the 14,100 generators recycled at least part of their hazardous waste. This approach avoids disposal cost.
3. **In-House Volume/Toxicity Reduction**—Treating waste at the source, so the final output is smaller and safer. Methods include better sorting of hazardous waste from nonhazardous waste, dewatering, and neutralization.
4. **Waste Fixation**—Bonding or "fixing" waste to relatively inert materials such as cement, so that ground water in a landfill won't leach toxics into water supplies.
5. **Incineration**—Burning of combustible waste, such as oils, solvents, and pesticides, to reduce the volume and usually leave a nontoxic ash for land burial. Incineration consumes a lot of energy and can pollute the air. Incineration at sea is being done on a smaller scale.
6. **Solar Evaporation/Land Treatment**—Evaporating liquid wastes in settling lagoons and mixing the residue into soil, where bacteria help to decompose organic waste.
7. **Chemical Treatment**—Reducing volume and toxicity so waste can be buried in landfills. Used extensively in refining, steel, automobiles, chemicals, and metal finishing. Methods include chemical reactions to make wastes less hazardous and more stable, neutralizing acids and caustics, and precipitation.
8. **Deep-Well Injection**—Used especially by refineries and petrochemical companies to pump liquid waste deep underground into geologically "safe" strata (porous rocks, isolated from drinkable water and minable minerals).
9. **Secure Landfills**—Land burial of waste, at a geologically-chosen site, protected by clay or plastic barriers to ground water, with a leachate collection system, and a ground-water monitoring system.

Secure landfills are the most-used disposal method. They can accommodate a broad variety of waste at a reasonable cost. And secure landfills accept the residue from other treatment methods, such as incineration and chemical treatment.

Because they are the ultimate disposal for most wastes, this booklet focuses upon secure landfills. It is the selection of geologically proper sites for these landfills that is the concern of professional geologists.

WHAT HAPPENS TO HAZARDOUS WASTE AFTER IT LEAVES A FACTORY?

An example of a hazardous waste is paint sludge. Sludge is an unavoidable byproduct of paint manufacturing, and millions of gallons of it must be safely disposed of each year. It is a hazardous waste because it may contain toxic metals (in the pigments) and flammable solvents.

Here is one scenario for managing this waste: (1) At the factory, sludge in labeled 55-gallon drums is recorded on a shipping manifest and trucked to (2) a solvent-distilling plant. Here solvent is recovered and (3) recycled back to the paint factory.

If there are (4) heavy metals in the sludge, such as lead and copper, (5) the sludge is treated and trucked to (7) a landfill.

If there are (4) no heavy metals, the waste is (6) used as furnace fuel, and the ash (7) buried in landfills.

This example shows how multiple waste-management methods (recycling, bonding, waste exchange/incineration, and secure landfills) can be used together.

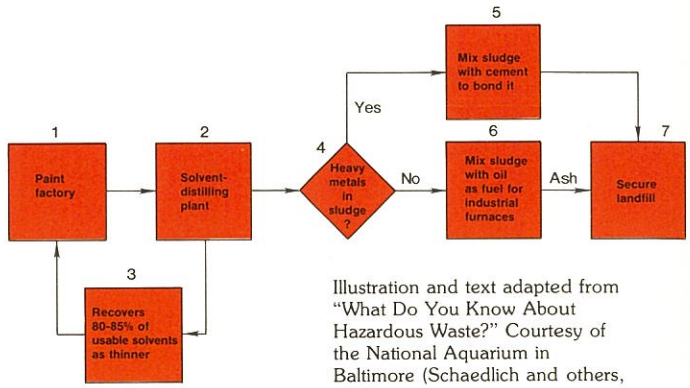


Illustration and text adapted from "What Do You Know About Hazardous Waste?" Courtesy of the National Aquarium in Baltimore (Schaedlich and others, 1982)

CECOS International

A Decent Burial

Secure land burial can prevent hazardous waste from escaping into the environment. If EPA's 1983 rules for burial remain unaltered and are strictly enforced, all new hazardous-waste landfills will theoretically be safe:

- Wastes are to be securely packaged, and segregated to reduce the risk of fire or explosion from chemical reactions.
- Waterproof plastic liners (1/32″ to 1/16″ thick) are required so that liquid-waste seepage and leachate cannot escape.*
- The entire vault is to be surrounded with clay, which provides a barrier to water and leachate.*
- A leachate-removal system is required in the bottom of the vault, and it must be operated "until leachate is no longer detected," which could be scores of years, or even centuries. A leak-detection system is also required.
- In most cases, ground water must be monitored by wells placed down-grade from the burial. Monitoring is required during operation of the landfill and for about 30 years after closure of the site.
- When the landfill is full and closed, it must be covered with an impermeable clay cap to prevent ground water from entering.

There is considerable debate as to the reliability of this arrangement. It is also expensive. However, the technology exists to meet the requirements.

* Most of the Nation's 75,000 industrial landfills, containing both hazardous and nonhazardous waste, have neither plastic liners nor clay barriers.

Anatomy of an Insecure Landfill. . .

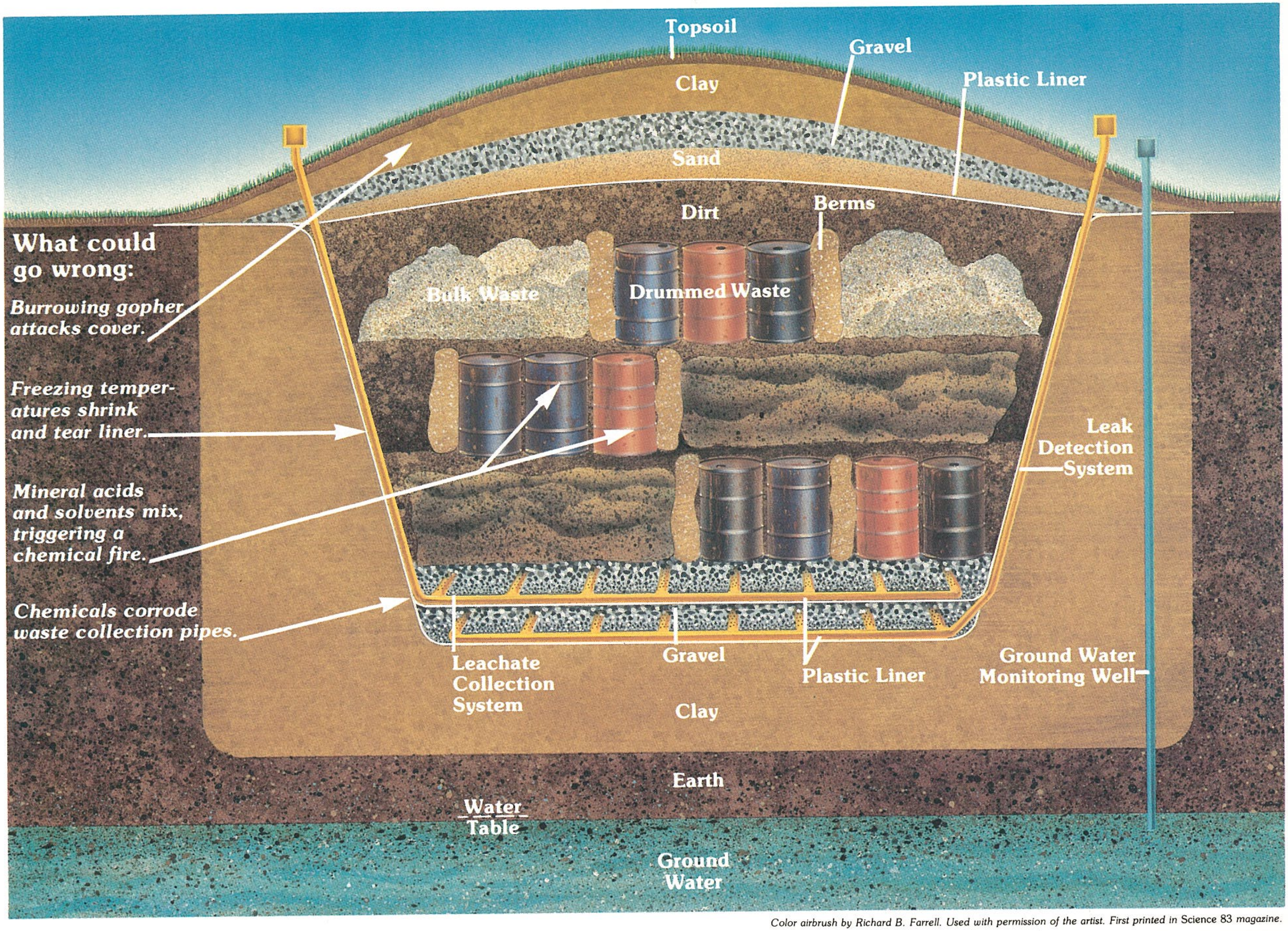
Hazardous wastes may remain dangerous for thousands of years, but even the most carefully designed landfill can start leaking in months. Below, in cross section, is what waste experts consider the closest thing to a secure landfill.

The landfill is a pit 60 feet deep, sealed in a liner 30 times the thickness of a plastic trash bag. Leachate, the liquid derived from wastes, inevitably seeps down to the bottom of the pit, passes through a one-foot layer of gravel and into perforated collection pipes. From there the leachate is pumped to the surface for treatment. Another liner, gravel bed, and pipe system give added protection, and a foundation of packed clay acts as a final defense. Exterior monitors check for chemicals leaking into the ground water.

Various forms of toxic waste—bulk trash, drums of chemicals, and sludges—are placed on the gravel and covered with dirt. Clay berms bulldozed against the waste give structural support and separate incompatible materials. The cover consists of another liner plus layers of sand, gravel, and clay shaped into a slope that diverts rainwater.

Landfills fail easily. Bulldozers can tear the plastic liner, and leachate can disintegrate it. "No liner can stand up to the range of chemicals found in a landfill," says Kirk Brown at Texas A & M. The weight of the waste may crush collection pipes, or debris may clog the perforations. The landfill's protective cover can be breached by erosion, by new construction on the site, or by slumping after bulk solids settle and barrels disintegrate below. If the cover cracks, rain can mix with waste, overloading the leachate collection system, or worse, causing the landfill to overflow. The best protection, say the experts, is an ideal environment: several hundred feet of natural clay, a dry climate, and a water table far below the surface.

—Modified from an article by Diana Morgan in *Science 83*



Color airbrush by Richard B. Farrell. Used with permission of the artist. First printed in Science 83 magazine.

How Geologists Pick Good Sites for Secure Disposal of Hazardous Wastes

We have seen what was wrong with old burial methods: landfill sites selected for convenience instead of geology, in steel drums that could rust through in a few years, buried in direct contact with percolating ground water that could leach toxics into drinking water and streams. It is little wonder EPA estimates that some 2,000 old disposal sites could threaten nearby populations. Many of these old sites would never have been created if a geologist had been consulted first.

Geologic Design of New Sites. When burying hazardous waste, one must critically examine the *geology* of the site—the soil and rocks, their stability, and water. When professional geologists are called upon to evaluate hazardous-waste landfill sites, here is what they look at:

- *Water and minerals that could be contaminated*—Are there aquifers (water-bearing rock layers that can supply drinking water) underneath the site that could be contaminated by leachate? Could leachate reach a stream or river that supplies a town's water? (Typically, a site must be at least 500 feet from the nearest well or stream.) Are there developable minerals (coal, petroleum, ores) that might become contaminated?
- *Topography*—Is the site on sloping land that would encourage precipitation runoff to flow across it, rapidly eroding away backfilled dirt, exposing the buried wastes? Is the site in a flood plain? (Flood-plain sites are prohibited.)
- *Land Stability*—Is the site prone to earth creep, landslides, or rapid erosion?
- *Bedrock Stability*—Is the bedrock fractured or faulted (broken)? Is it undermined, leading to subsidence? Are the rocks likely to be disturbed by earthquakes?
- *Soil and Rock Characteristics*—How readily will ground water percolate through the soil and rocks? Is the bedrock thick enough and impermeable enough to halt the flow of leachate? Will the leachate react chemically with the bedrock?
- *Water*—Is there heavy precipitation in the area, making leachate production more likely? Is the water table below the level of burial? What is the rate and direction of ground-water flow?
- *Construction Materials*—Secure landfills must be lined with an impermeable material, such as a clay. Is suitable clay available nearby?

(Text continues on facing page)

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All these aspects are critical to constructing new facilities, altering existing ones, or designing remedies for abandoned sites.

The geologist first chooses several possible sites, based on a study of topographic maps, geologic maps, ground-water maps, aerial photos, and site visits. The next step is detailed investigation of each site, including test trenches, borings, waterflow studies, rock-structure studies, and laboratory analysis of barrier materials. Products of this work include detailed site maps showing geologic structure, water flow, rock chemistry, cross sections to show how the rock layers lie, and recommendations.*

Clearly, geologic investigation of potential sites is a complex task. The geologist must be made a part of the team from the very beginning, because it is pointless to waste engineering, architectural, and construction time on a site that is geologically unfit.

While there is no "perfect" site, a professional geologist can identify potentially secure landfill sites, and then investigate each one, reporting the pros and cons to the rest of the design team. Several states have programs to aid such teams in site searches.

In studying a potential, hazardous-waste burial site, the geologist is looking at a two-way street:

→ The effects of existing geologic conditions on the proposed landfill

← The effects of the landfill on future geologic conditions of the area

These relations are the key to the long-term safety of the landfill.

The bottom line: Professional geologists must be involved in every step of siting a secure landfill, or cleaning up an abandoned dump. Professional geologists can provide much of the factual information that decision-makers must have.

* For abandoned sites, site plans or maps may not exist, and vegetation may obscure the site. In such cases geologists will study past aerial photos to see how the site developed; determine conditions by drilling, trenching, ground radar/sonar, and magnetic detection; and recommend actions to the cleanup team.

CLAY, THE GEOLOGIST'S CHOICE

The ideal "natural" secure landfill site would have the water table below the bottom of the burial pit, would be in a dry climate with very little ground water percolating around it, and would be in clay hundreds of feet thick. Because very few sites meet these criteria, our geologic and engineering technology must transform imperfect real-world sites into safe ones.

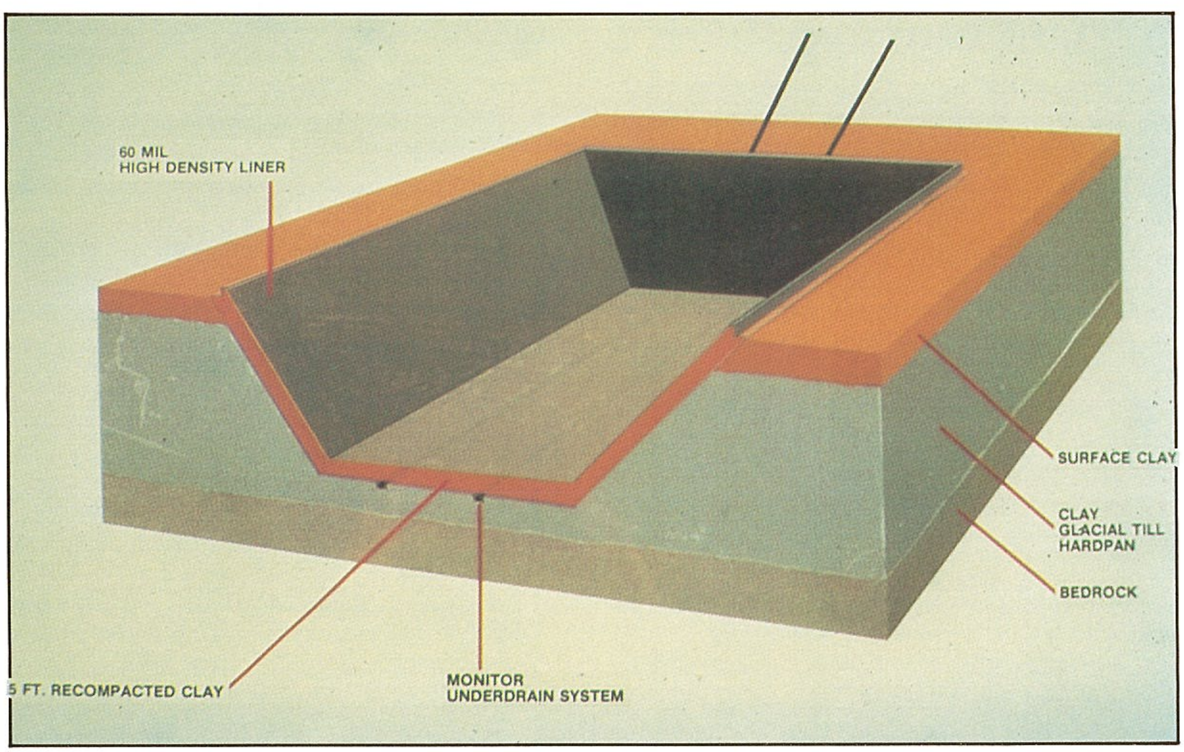
In designing the burial vault, geologists again play an important role. They select the natural earth materials, usually dense clays, to form an enclosure for the vault. The clay is an important barrier to the entry of ground water, and to the outflow of waste seepage and leachate.

Clays are usually the material of choice because they consist of tiny flat plates so tightly packed together that they severely restrict the flow of water. (This effect is visible in areas having clayey soils: after a rain, puddles will linger because the water cannot soak through the poorly permeable clay.)

Geologists must consider both the chemistry of the waste, and the chemistry of the clay in which it is to be placed. This is necessary because the wastes and clay can chemically react in two important ways:

1. On the bad side, the clay can be chemically attacked by leachate, reducing its ability to contain the liquid.
2. On the good side, clays can actually detoxify some leachates, by the "ion exchange" process. This works in a manner similar to ion-exchange water softeners, which donate innocuous ions to the water while absorbing undesirable ones in exchange. If the chemistry of waste and clay are compatible, the clay will donate harmless ions to the leachate, in exchange for toxic ions. The toxic ions will bond to the clay indefinitely. Unfortunately, clay's capacity to "scrub" leachate is finite, and once the clay is saturated with toxic ions, leachate will pass through unchanged.

Clay is not perfect. It is subject to erosion, cracking, root penetration by plants, burrowing animals, worm holes, and damage from human activities. Still, it is the best readily available, cheap natural material to use.



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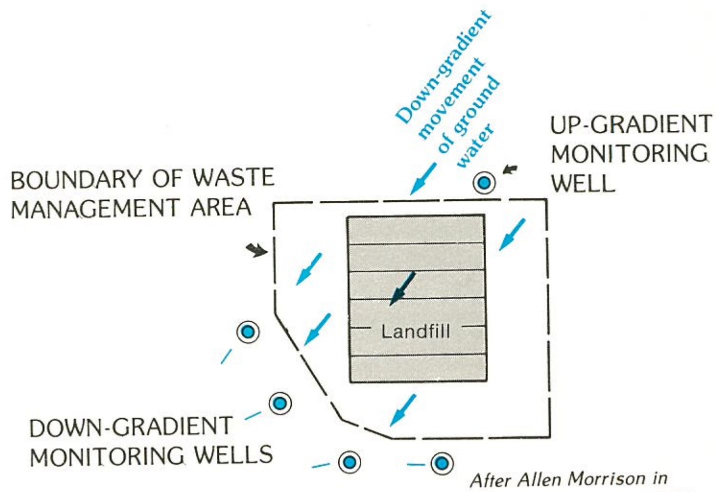
Ground-Water Monitoring

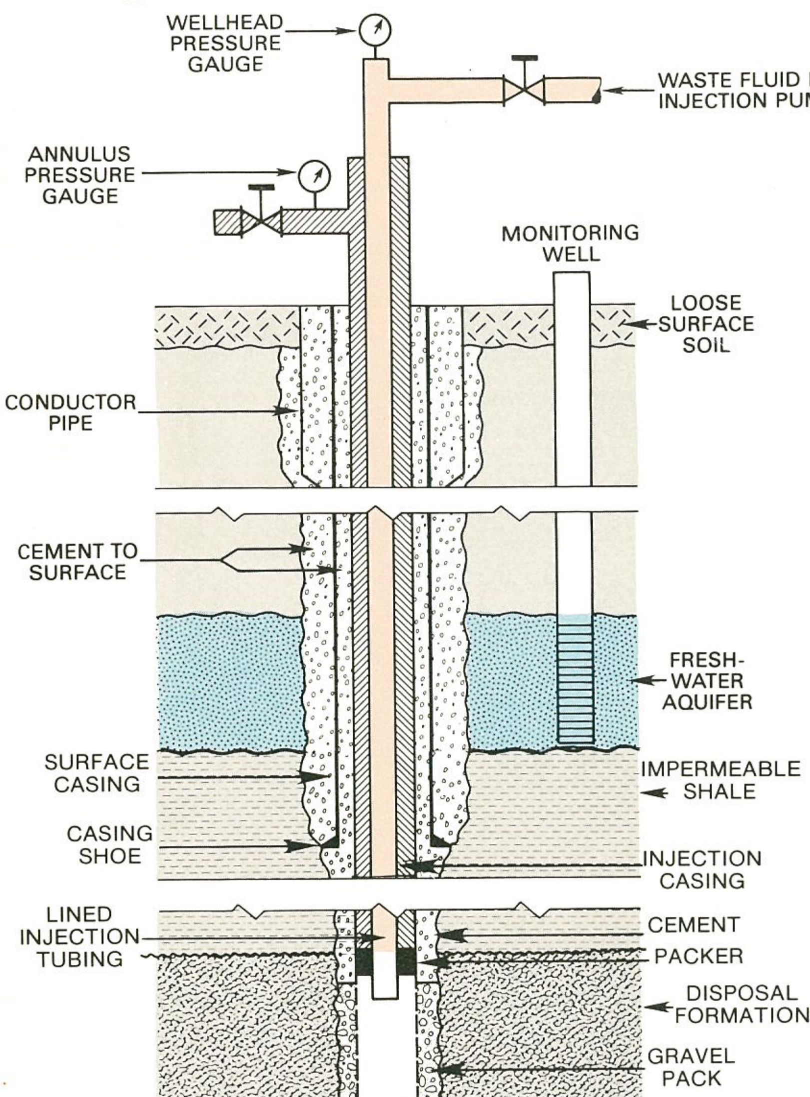
EPA requires surveillance of ground water adjacent to the hazardous-waste site, to detect any changes in quality that would betray leakage from the landfill. Monitoring wells must be located by the geologist as part of the initial site plan to assure that performance standards are met. The geologist determines the exact placement and depth of wells, based on ground-water flow and the nature of the rocks. Monitoring nearby ground water provides early warning of any contamination, so that remedial action can be taken, reducing environmental damage.

In the illustration, water quality is monitored both up-gradient from the landfill, and down-gradient. The results are compared. Any difference indicates possible leakage from the landfill.



After Allen Morrison in Civil Engineering - ASCE

Deep-Well Injection of Liquid Waste



Toxic liquid wastes and other noxious fluids may in some places be safely injected into deep permeable rocks far below fresh-water aquifers. Such disposal is generally to deep saline (or otherwise unusable) ground waters that are isolated from fresh-water sources. Great care is required in well-casing design and operations to avoid leakage that could endanger usable fresh-water supplies. It is important in site selection to choose places where the hydraulic head of the injection can be dissipated to avoid applying excess pressure to the well system or the receiving zone.

Properly constructed oil wells are cased in similar fashion, to safeguard ground waters, but in many old-producing districts saline water escapes through leaky casings and holding ponds, causing extensive local contamination.

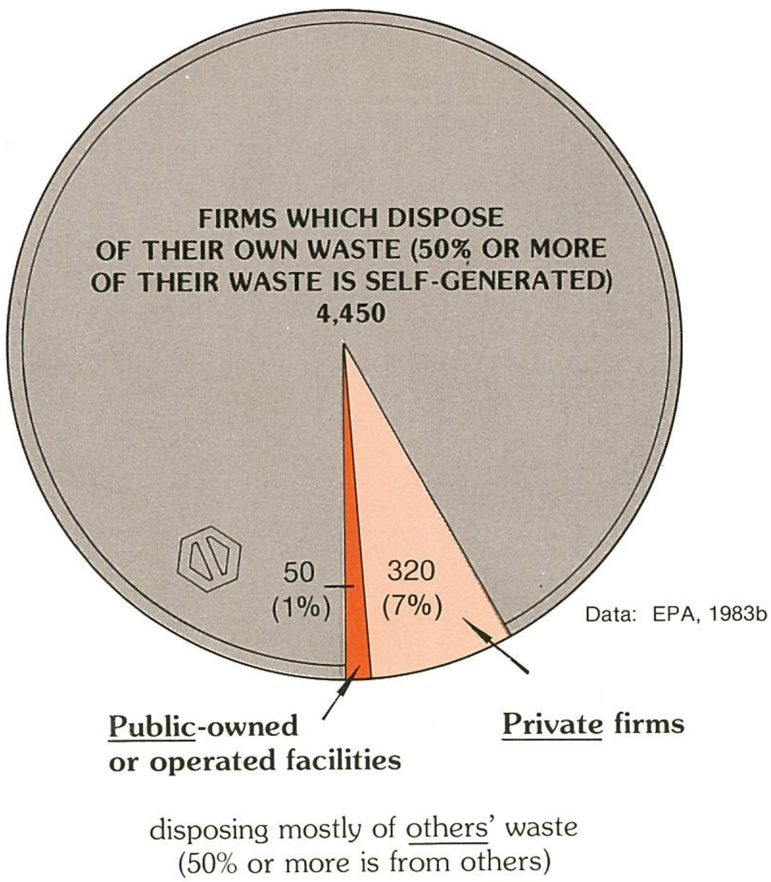
Who Does the Disposing?

In 1981, about 95% of all hazardous waste was disposed of on-site at the point of creation, predominantly by landfill, incineration, chemical treatment, and deep-well injection.

The other 5%, about 2 billion gallons, was hauled in tank trucks and drums over public highways to the 4,820 treatment, storage, and disposal (TSD) facilities then in operation, there to be stored, handled, and disposed. EPA says these facilities can handle the present level of waste in most parts of the U.S., but future capacity is uncertain. It depends upon:

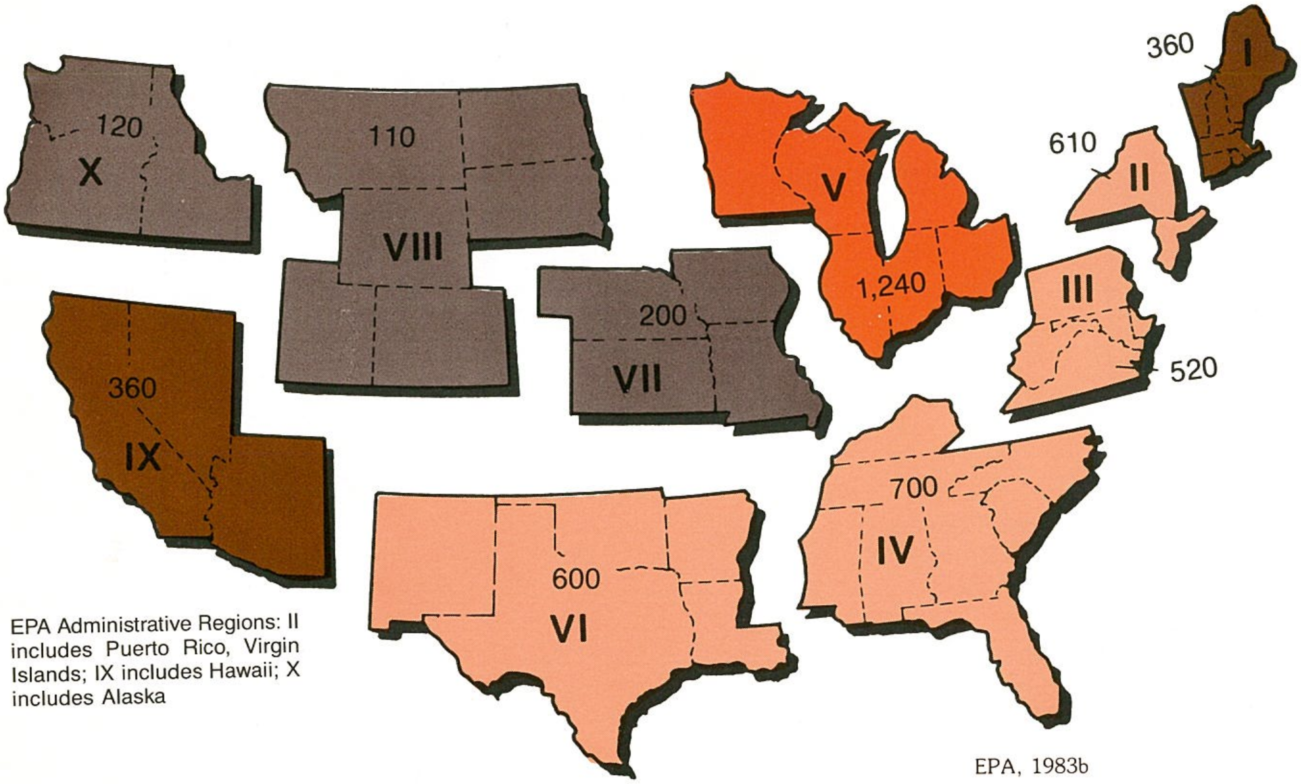
- Public resistance to siting plants and to hauling
- Industry's changing the amount of waste it produces (or their contracts for its removal)
- EPA rule changes
- Profits-vs.-risks of the disposal business

The Business of Treatment, Storage, & Disposal



HAZARDOUS-WASTE TREATMENT, STORAGE, & DISPOSAL FACILITIES

4,820 TSDs in 1981



EPA Administrative Regions: II includes Puerto Rico, Virgin Islands; IX includes Hawaii; X includes Alaska

EPA, 1983b

The facilities providing these services:

- Treatment at 1,500 facilities
- Storage at 4,300 facilities
- Disposal at 430 facilities

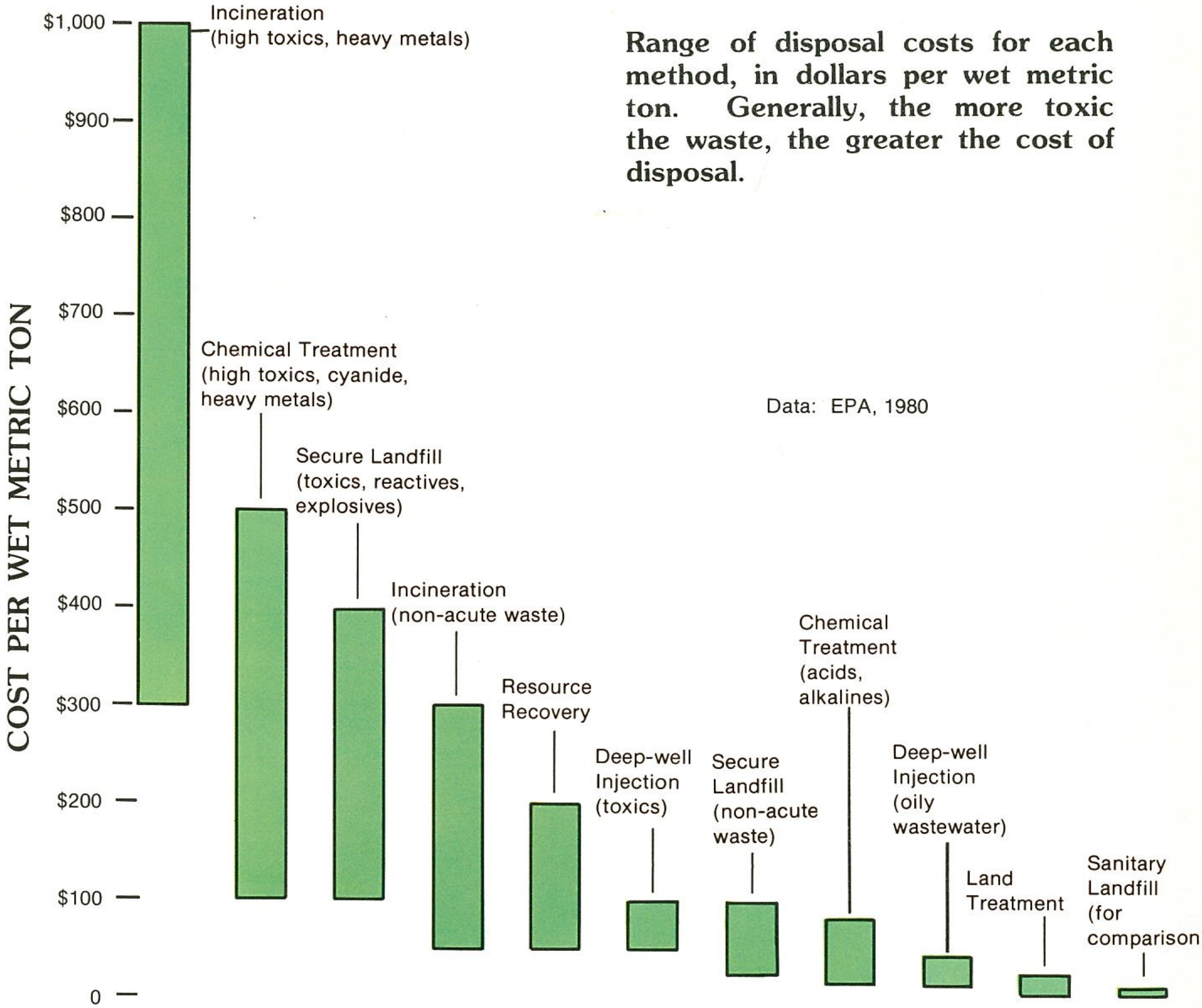
Some operations provided multiple services.

Number of facilities that used various disposal methods:

770 - Surface impoundments (lagoons or settling ponds)
610 - Treatment tanks
240 - Incineration
200 - Landfill
170 - Waste pile
90 - Injection well
70 - Land treatment
320 - Other processes

Storage containers were used by 3,580 TSDs, and storage tanks were used by 1,430.

Disposal Dollars



Range of disposal costs for each method, in dollars per wet metric ton. Generally, the more toxic the waste, the greater the cost of disposal.

Data: EPA, 1980

The Social Side of Siting

As if the geological and engineering problems were not enough, these *social* factors (adapted from an EPA report) figure in future siting of secure hazardous-waste landfills:

- Importance of the waste-generating industry to the local economy
- Reputation of the waste-management contractor, or local waste-management authority
- Existence of recognized well-managed (or notoriously poorly-managed) hazardous-waste facilities in the area
- Active State-government encouragement of a new facility
- Involvement of public officials and citizens early in site selection
- Placing sites well away from residential areas, schools, hospitals, and nursing homes
- Exclusion from the landfill of public-perceived high toxics (for example, dioxin, PCBs)
- Demonstration of thorough geological evaluation, engineering, and planning
- Full disclosure by all parties of plans and problems

Much of the above relates to *risk assessment*—evaluating the *probability* of hazardous waste actually harming someone. Risk assessment is complex, involving trade-offs among the likelihood of exposure, likelihood of injury, cost to the waste generators of achieving different degrees of security in isolating wastes, cost to the government and tax consequences, and so on.

High-Tech Future for Hazardous-Waste Disposal?

Emerging technologies promise better methods, but most are far from operational. Some old problems remain—storage, shipping, operating safety, emissions, and cost. Here are methods in the works, and their stage of development:

R & D	• Molten sodium decomposition • Chlorinolysis of organic waste • Ozone oxidation	• Wet air oxidation • Microwave plasma disintegration • Ultraviolet radiation
***Pilot Plant* (simulated conditions)**	• Land treatment (of other than conventional petrowastes) • Molten salt combustion	• Cement kilns (burning waste as fuel)
***Demonstration Facility* (actual conditions)**	• Fluidized bed combustion	
Commercial Operations	• Waste-fixation • Incineration-at-sea	• Comingling of hazardous/non-hazardous waste

Role of Hazardous Waste In National Planning

America generates a tremendous volume of wastes that are hazardous to the public, the environment, and the continued productivity of industry. For many reasons, our handling of such wastes in the past was unfortunately profligate.

The public, industry, and government now recognize that safe disposal of hazardous wastes is essential to the Nation's health, industrial production, and economic condition. We have recognized our collective responsibility as custodians of our share of the earth.

Legislation of the past decade, particularly the Resource Conservation and Recovery Act of 1976 (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA or Superfund) are important steps in cleaning up the hazardous past and preventing a hazardous future.

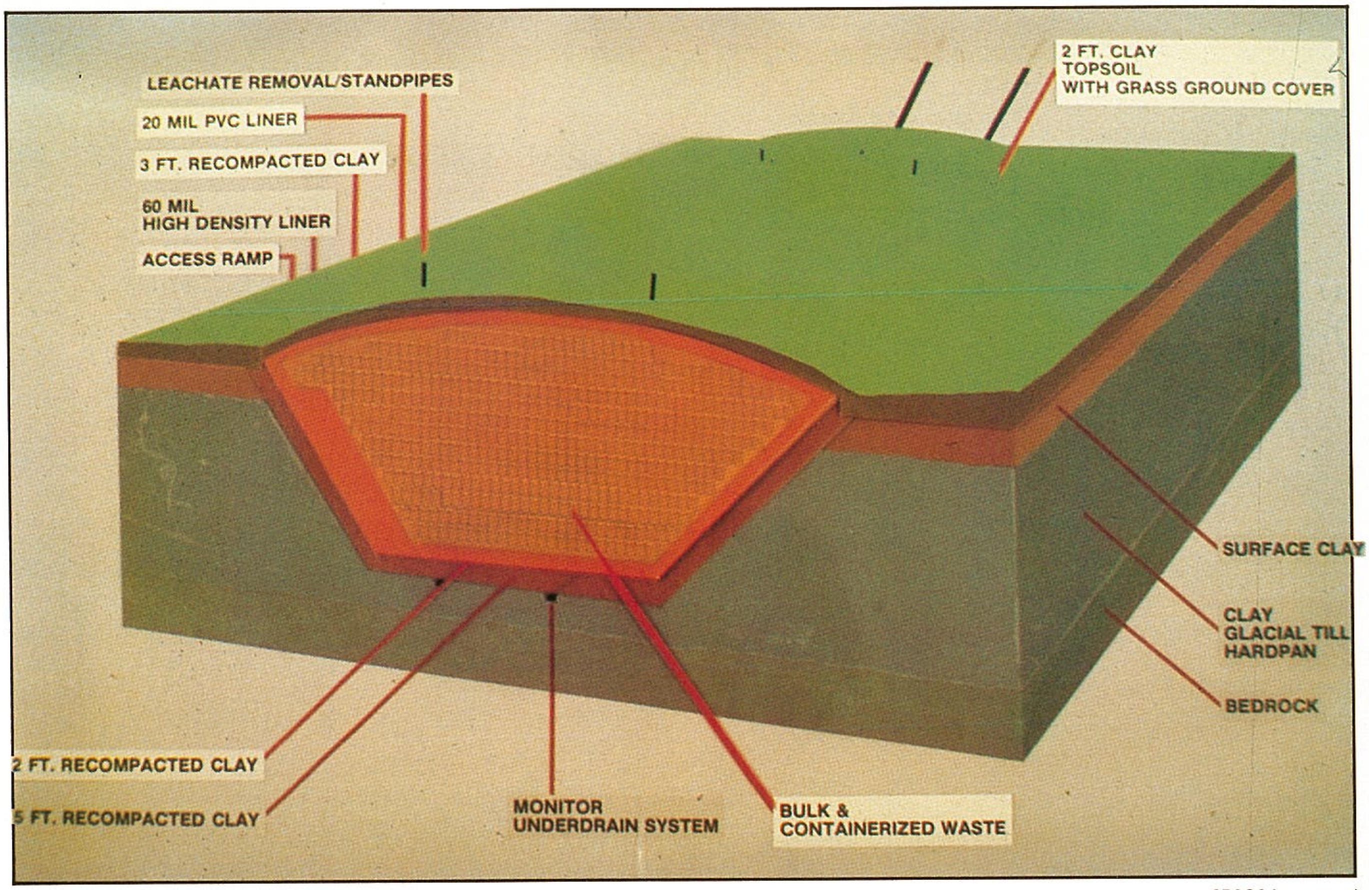
The technology exists to clean up the past and to secure the future. Continuing research and development are discovering better methods for reducing dangerous waste production, and rendering harmless the waste that is produced.

Inadequate communication among the public, industry, and government has left a legacy of distrust and fear. Closer affiliation of these groups, plus involvement of objective professionals in geology, is fostering increased mutual understanding of solutions, and their vital role in the Nation's future.

The magnitude and complexity of the Nation's hazardous-waste problem continues to grow. For this reason, unceasing effort is needed to continue research, to preserve and improve the regulations that are presently in place, and to keep awareness of the problem in the mainstream of planning, management, and decision-making at all levels of government.

AIPG Policy on Key Hazardous-Waste Issues

1. **Secure land burial** can provide safe, effective, cost-efficient hazardous-waste management in many locations.
2. **Geological suitability** of potential sites can now be determined, and our methods will improve as research and practice proceed.
3. **Detailed geological investigations** are mandatory in selecting sites for secure land burial of hazardous waste.
4. **Federal regulations imply** that engineering can overcome the geological limitations of poor sites (disregarding cost), but AIPG believes that sites must demonstrate strong *natural* capability to isolate wastes from the biosphere for hundreds or thousands of years. In fact, some areas are too risky for even the best landfill technology to secure.
5. **An objective setting** of full information disclosure must exist for successful site selection. This is necessary to establish trust and cooperation among an informed public, legislators, government agencies, industry, scientists, and academics.
6. **Public education** must be promoted to improve everyone's ability to intelligently deal with the hazardous-waste problem.
7. **Scientific research** must be promoted to improve our technology, particularly in the areas of resource recovery, waste exchange, reducing the volume and toxicity of wastes, and waste treatment.



CECOS International

Landmarks in Hazardous-Waste Regulation

1965 — Solid Waste Disposal Act

1972 — Clean Water Act (covers industrial discharges into streams, lakes, and oceans, and provides funds for cleanup of hazardous waste and oil spills into navigable waterways)

1972 — Marine Protection, Research and Sanctuaries Act (covers ocean dumping/incineration)

1973 — President's Council on Environmental Quality calls attention to the threat from improper disposal

1974 — Safe Drinking Water Act (regulates underground injection of wastes)

1975 — Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)—enacted 1948, revised 1975 and 1978

1975 — Hazardous Materials Transportation Act (covers packing and shipping)

1976 — RCRA, Resource Conservation and Recovery Act (first comprehensive legislation covering hazardous-waste disposal)

1976 — Toxic Substances Control Act (regulates manufacturing, distribution, and use of toxic chemicals, including PCB disposal)

1979 — Clean Air Act (sets emission standards for hazardous pollutants)

1980 — "Superfund"—Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)—provides $1.6 billion to help states clean up abandoned waste sites

Glossary

Hazardous waste has its own special terminology, and an understanding of these terms is essential. The definitions here are adapted from AIPG 1983, Studdard 1974, and Ohio EPA.

***Absorb*—**Adhesion of toxic compounds to the surface of clay granules.

***CERCLA—Comprehensive Environmental Response, Compensation, and Liability Act (Superfund)*—**See Page 9.

***Cradle to grave*—**Handling of hazardous waste from creation through ultimate disposal.

***Deep-Well injection*—**See page 17.

***Dioxin*—**A chemical family of 75 compounds; most toxic is 2,3,7,8-tetrachlorodibenzo-p-dioxin, TCDD. Stable, slow to decompose byproducts of herbicide manufacturing. Found in some herbicides, preservatives, and Agent Orange.

***Fixation of Waste*—**See page 10, number 4.

***Geology*—**The science of the earth, its forces, rocks, ground water, and natural hazards.

***Ground water*—**Water existing in the soil and rocks, below the land surface (*surface waters* refer to lakes, streams, and rivers).

***Hazardous waste*—**Waste that threatens living organisms because it is toxic, flammable, explosive, corrosive, radioactive, or biologically viral. (See Toxic Waste)

***Hazardous-waste management*—**Systematic control of hazardous-waste transportation, handling, and disposal.

***Lagoon*—**Shallow pond where wastewater is partially purified by sunlight, oxygen, and bacteria.

***Land treatment*—**See page 10, number 6.

***Leach, leachate*—**When water percolates through a material, it dissolves (leaches) the soluble compounds from the material. The resulting solution is *leachate.* A coffee percolator makes coffee in this way; coffee is a leachate.

***Liner*—**Plastic membrane and(or) clay layer in a secure landfill, designed to prevent the entry of ground water and the exit of liquid leachate.

***Manifest*—**A shipping document, now required by EPA for all hazardous-waste shipments, naming the material, quantity, origin, route, and destination.

***Metric ton*—**1,000 kilograms, or 2,204.6 pounds. 1.102 x metric tons = U.S. standard short tons (2,000 pounds). 0.907 x U.S. short tons = metric tons. Waste is expressed in "wet" metric tons, WMT, a more practical unit than the weight of dried waste.

***National Priority List*—**EPA's list of hazardous-waste sites eligible for cleanup under Superfund.

***PCBs*—**Polychlorinated biphenyls, fire-resistant organic fluids used in making plastics and as insulation in heavy-duty electrical equipment. Highly toxic, slow to decompose, cumulative in the body. No longer made in U.S., but much exists in power transformers and old dumps.

***Percolate*—**Movement of water downward through soil and rock.

***RCRA—Resource Conservation and Recovery Act*—**See page 8.

***Resource Recovery*—**See page 10, number 2.

***Sanitary landfill*—**Burial of nonhazardous waste such as garbage. Some hazardous waste exists in old sanitary landfills due to lack of regulation, and some is legally placed in modern landfills by small-volume waste generators, who are exempt from EPA's rules. (See Secure Landfill)

***Secure landfill*—**Burial of waste, in containers, at a geologically-chosen site, protected by clay or plastic barriers to ground water, with a leachate-collection system, and a ground-water monitoring system. (See Sanitary Landfill)

***Superfund*—**See page 9.

***Toxic Waste*—**Material that will produce injury or disease upon exposure, ingestion, or inhalation. (See Hazardous Waste)

***TSD facility*—**Treatment, storage, and disposal facility for hazardous waste.

***Waste-exchange*—**See page 10, number 2.

***Water table*—**Ground water percolates downward until it saturates all the pores in the soil and rock. The upper edge of this saturated zone is the *water table.*

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