To Rot or Not

Arizona Garbage Project

Above: Despite its near-pristine look, this front page spent 18 years in a landfill in Tempe, Ariz., and serves to illustrate how slowly even biodegradable wastes rot.

Landfill designers argue the benefits of burying garbage wet vs. dry

By DIANE E. LOUPE

Archaeologists at the University of Arizona's Garbage Project unearthed disturbing surprises while excavating landfills during the late 1970s. In the Chicago area, for example, they exhumed graying, mummified remains of 20-year-old hotdogs. They plunged a bucket into a mass of gray slime, and found yard wastes undecayed after 15 years awash in sewage sludge. They retrieved a 1952 newspaper from a landfill and found it was still readable, as were scores of old magazines, envelopes and other papers, recalls project co-director Wilson W. Hughes.

Though a boon to archaeologists, such finds spell bad news for landfill managers. Clearly these "biodegradable" products were not degrading as they should.

For years, landfill managers assumed that the piles of paper products, yard wastes and food scraps they buried in landfills decomposed readily. But as the Arizona project so vividly demonstrated, many landfills instead preserve garbage by sealing it from the rotting influences of air or moisture.

Today, several research teams are working to redesign landfills so that interred wastes indeed rot. They contend that landfills not only should be wet, but also should swirl moisture and bacteria around garbage so that buried wastes decay quickly. Some scientists and regulators disagree, arguing that communities should entomb wastes in permanent graves — essentially embalming them so interred pollutants can't leach out with percolating rainwater to contaminate aquifers or generate a potentially explosive buildup of methane as organic wastes decay.

The fate of the nation's growing garbage output — nearly 91 million tons in 1986 — hangs on such debates. U.S. households will send nearly 170 million tons of waste to municipal landfills annually by the year 2000, the Environmental Protection Agency estimates. While this projection reflects an increasing demand for landfills, the supply of landfill space is shrinking — precipitously.

A 1989 Office of Technology Assessment (OTA) report estimated that 80 percent of existing landfills will be filled and closed within 20 years. Landfill closings may accelerate this winter, when EPA plans to issue new guidelines for managing municipal solid waste.

The growing mismatch between the supply and demand for landfill space has sent garbage disposal costs skyrocketing. Annual surveys of 72 municipal solid-waste landfills by the National Solid Waste Management Association show that between 1982 and 1988, the average cost to dump wastes more than doubled — from $10.80 per ton of delivered garbage to $26.93.

For landfills to remain a viable waste-disposal option, waste analysts point out, garbage burial practices must change. And one idea gaining popularity involves adding water.

"We favor accelerating biodegradation by adding moisture and other things to try to compress the active biological life of a landfill" — from 40 or 50 years to just five or 10 years, says chemical engineer James J. Noble at Tufts University in Medford, Mass.

Though landfilled wastes are supposed to decay, the "dry" burial practices commonly used today may delay significant degradation for half a century or more, Noble observes. By choking off the oxygen that some microbes need and by withholding the water required to foster microbial decay, dry landfilling slows degradation.

Moreover, Noble notes, since municipal wastes can involve a dangerous mix of pollutants, someone has to babysit these landfills until their contents degrade. According to a 1988 EPA report, landfills can harbor any of more than 200 chemicals, including the carcinogens arsenic, methylene chloride and carbon tetrachloride. And several researchers have already observed that the breakdown of landfilled wastes containing trichloroethylene, a solvent, can yield detectable quantities of vinyl chloride, another potent carcinogen. To date, EPA says, one-quarter of all monitored municipal landfills in the United States are leaking their contents into groundwater.

Most landfill biodegradation results from the complex interactions of three classes of soil-dwelling bacteria. Cellulolytic microbes initiate the process by cleaving the cellulose in paper, wood and other plant wastes. Bacteria called acidogens then take over, fermenting these sugars into weak acids. Methanogens complete the decay by converting the acids into carbon dioxide and methane.

If researchers can map the optimal interplay of these "bugs," they might learn how to manipulate levels of the organisms to accelerate degradation, Noble says. But striking the right balance is tricky. "If the acid formers do their job too well" – as he says often happens in wastewater treatment plants – "they can kill the methanogens."

One key to accelerating landfill biodegradation, Noble suggests, is spurring initial bacterial decay. Toward this end, he has experimented with soaking paper, grass and other landfill wastes in naturally occurring cellulolytic bacteria. Untreated wastes usually take about 40 years to decay, but in Noble's laboratory experiments, heating reduced the decay period to one month, he says.

The wet landfill's more rapid decay can pose some potential drawbacks, such as accelerated methane generation. In 1969, gas seepage from a nearby landfill led to a methane explosion in a National Guard Armory in Winston-Salem, N.C., killing three guardsmen and seriously injuring 25 others. Since 1984, explosions or fires triggered by landfill gas have taken eight more lives in the United States.

Wet-landfill proponents argue that such problems can be controlled at well-managed sites. Indeed, says Noble, high-volume methane production improves the economics of extracting landfill gas as an energy source. Methane from the Puente Hills landfill in Los Angeles, he notes, now powers a 60-megawatt steam turbine, supplying power to 3,000 homes.

Critics of wet landfills point out that moister conditions increase the risk of pollution leakage and groundwater contamination. But University of Pittsburgh environmental engineer Frederick G. Pohland counters that "you're not going to leave [a landfill] open like a bathtub." What many critics overlook, he says, is that "you don't continue to accumulate moisture beyond what you need to manage."

As a further precaution against leakage, Pohland pioneered the concept of recirculating leachate – the liquids draining out of landfills. Through two decades of studies using experimental landfills, he has found that collecting and recirculating moisture reduces the potential for leakage, hastens organic-pollutant degradation and cuts the landfill's stabilization or decay period – where leakage poses the greatest threat – from decades to a few years.

More than 100 U.S. landfills now collect and recirculate their leachate, Pohland says. His data indicate that the moist conditions in these landfills foster the microbial conversion of 90 or 95 percent of most readily degradable organic chemicals to gas. The challenge is to find the right mix of wastes and moisture, since too much toxic material can kill the natural microbial communities that promote decay.

Pohland has also conducted studies showing that the recirculating leachate tends to deposit many heavy metals into the decaying matter in the landfill. For example, he and J.P. Gould, of the Georgia Institute of Technology in Atlanta, demonstrated in 1987 that recycling leachate reduced the toxicity of heavy metal sludges by precipitating sulfides, carbonates or hydroxides out of the leachate and into landfill soil, where they became immobilized.

Analytical chemist Wendall H. Cross, also of Georgia Tech, is studying pesticide transformation in the same self-contained experimental wet landfills, which he says smell like "a combination of sweat and wet goats – definitely not like Chanel No. 5."

Two pesticides he added along with other pollutants to these experimental systems did not appear in the leachate collected from the bottom of the landfills. Cross says this suggests they had either bound to the garbage or biodegraded.

Current EPA regulations favor dry landfills. They require that such garbage pits be lined with an impermeable barrier – usually a rubber or plastic liner – to prevent liquids from escaping. Mike Flynn, an EPA official in Washington, D.C., says that the proposed tougher landfill controls due out this winter would further limit the introduction of liquids to landfills by banning bulk liquid disposal such as watery sewage sludge.

"We were concerned about increased liquid leading . . . to potential groundwater contamination," says Flynn. Though the proposed regulations would allow leachate recirculation, they would also limit this to landfills with specially designed liners made from clay and synthetic materials.

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Prospectors mine landfills for profit

Early in his career, Robert E. Fahey mined Ohio coal. Now, as solid-waste director of Collier County, Fla., he mines garbage.

Fahey first proposed mining landfills in 1985, when Collier County was considering a garbage-fueled electric generating station. When officials scrapped plans for the incinerator two years later, he set about pioneering an alternative form of resource recovery – excavation of buried trash and extraction of recyclable materials.

To date, the most valuable commodity he has excavated is the dirt used as landfill covers. Fahey realized he could excavate soil from closed landfills for $1.59 per ton – less than half what others charged to deliver the dirt his landfill operators needed to cover refuse at active sites. Recycling this dirt saved the county $100,000 in 1989, he says. Fahey expects to reap additional savings by reclaiming space from these mining sites for future rubbish burial, and eventually by selling some of the aluminum, plastic, glass and rubber he's retrieving. Recovered ferrous metals already bring $10 a ton, he notes.

"A landfill is similar to a long-term compost operation," Fahey says. "During the time solid waste is resident in a landfill, it is undergoing chemical, biological and physical change." Though a landfill's largely anaerobic environment inhibits the corrosion of most metals, anaerobic microbes do help clean interred wastes by removing labels, glue and leftover foods or beverages from such items as metal cans and plastic soft-drink bottles.

Excavation is also the time for landfill improvements, such as installing new, nonpermeable liners to limit groundwater contamination from leaking wastes, he says.

Fahey acknowledges that his form of prospecting carries some risks. For example, though municipal landfill operators are not supposed to accept toxic, corrosive or explosive wastes, many unwittingly do. Excavators who inadvertently uncover such hazardous substances may face serious health threats, says chemical engineer James J. Noble of Tufts University in Medford, Mass.

But Fahey contends that most communities have relatively benign waste streams and few problems with toxic materials. Any toxic wastes received for burial could be earmarked for special segregated disposal, he says, at sites designated off-limits to mining.

Noble questions whether mining will prove as profitable in drier states, where wastes decompose more slowly. A 1987 report by his Center for Environmental Management at Tufts concluded that the difficulty of recovering metals from landfills suggests few offer much prospect for profit.

Communities in Delaware, Florida and New York are currently investigating landfill excavation, Fahey notes. And he's patenting a landfill-mining process that would involve the carefully controlled addition of moisture and methane-producing microbes to accelerate biodegradation before excavation and mining.

Seeking the optimal conditions and technologies for garbage prospecting, engineers at the University of South Florida in Tampa have just started a two-year research project designed to evaluate various types of equipment, moisture levels and site structures.

– D. E. Loupe

Photo: NSWMA

capable of rapid, error-free multiplication of large numbers. Then the real headaches began.

Commercially available integrated-circuit components limited the word size to 257 bits. Wiring constraints restricted the size of the boards on which the electronic parts could be mounted. Instead of laying out the computer on a single circuit board, the designers had to break up the circuitry to fit onto six boards – each a square 25.6 inches wide, densely packed with chips and covered with a rat's nest of connecting wires.

Before Younis could set the first chip into place, the researchers had to check their design for flaws. The trouble was that they had designed Little Fermat to have capabilities exceeding those of any conventional computer that could be used to simulate the way its logic worked. In the end, they had to settle for testing their design in pieces, never as a complete unit.

"Even then, it was a staggering task," Gregory Chudnovsky says.

Younis spent more than a year building the computer, then roughly another year testing the completed machine to correct all the assembly and design defects that he found. The biggest assembly problems involved the 82,500 individual wires (totaling about 5 miles) connecting 6,700 integrated-circuit chips and other components.

Those problems ranged from chips that sporadically continued working even when no electrical power reached them to wires that shrank and disconnected when they cooled after the machine was turned off. And because the computer was designed for rapid calculation, and electronic signals travel at finite speeds, even wire length became an important consideration. The most nightmarish defects – especially those that made their presence felt intermittently – took weeks to track down, but Younis persisted.

"Now it's running," David Chudnovsky says. "Rarely has a hardware project of such magnitude been carried through to its completion by a single man. It was an unbelievable achievement."

To compute with Little Fermat, a user writes a program in a language now called Younis. That language provides a set of instructions expressed in 240-bit chunks, which can be combined in various ways to perform a number of functions. A personal computer attached to Little Fermat loads the program into the machine, monitors the computation and unloads and displays the results when the computation is finished.

"We are now checking [Little Fermat's] performance," Gregory Chudnovsky says. "We have to be sure it does what we want it to do. And we would be happy to find someone interested in programming the machine for a specific application."

So far, the Chudnovskys have used Little Fermat primarily for computations in number theory that involve gargantuan numbers – searching for prime Fermat numbers, factoring large numbers and testing whether certain huge numbers are primes.

But the machine's special characteristics make it ideal for digital signal and image processing, as well as for solving the differential equations used by researchers modeling the behavior of physical systems. Such computational problems regularly surface in aerodynamics, hydrodynamics, chemistry, geophysics and many other disciplines.

Only one Little Fermat exists today, but that's more than can be said for the many other new computer designs that never made it to the hardware stage, instead remaining "paperware" – described in a paper but never built. "This machine is alive and well and working," David Chudnovsky says. "It's real."

"We showed it can be done," Gregory Chudnovsky says. "Even if it remains a one-of-a-kind machine, Little Fermat stands as a demonstration of what should be added to a supercomputer to improve its performance. It would be very cheap to put additional Fermat circuitry into future supercomputers." □

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Across the country, in the deserts of New Mexico, Thomas E. Hakonson is testing landfills designed to stay bone dry. As manager of environmental sciences research at Los Alamos (N.M.) National Laboratory, Hakonson strives to eliminate any chance of leachate formation in the experimental dump sites he's designing. His approach is to capture any precipitation at the surface, before it penetrates the landfill, and to return that water to the air via evapotranspiration by plants.

Using computer models, Hakonson also analyzes data on water migration, soil composition and erosion to design sloping gravel covers that wick moisture laterally away from wastes. Large rocks buried below topsoil prevent burrowing animals and roots from penetrating wastes buried below. But a key to these garbage vaults is the covering of native foliage planted atop them. Hakonson selects the plants for their ability to drink up rain or dew.

Systems that rely on synthetic flexible liners to entomb wastes eventually break down, Hakonson observes. His design "is less prone to failure because it uses natural components," he says. "We've got forests of juniper trees, grasses and weeds." Such environments are very stable, he adds: "They've been here hundreds of years."

Though officials at the Los Alamos facility would like to use these structures for hazardous waste disposal, Hakonson says his landfills could just as readily store municipal garbage.

Preliminary studies indicate the newly designed waste sites offer safe, long-term storage in the dry Southwest. To learn whether they will provide comparable security against leakage in wetter, colder climes, Hakonson has set up experimental models at Hill Air Force Base in Ogden, Utah. This should prove a true challenge of the system's universality, he says: "Snow comes in the winter and melts in the spring [when plants aren't transpiring]," he says, "so the mechanisms for removing water are low."

Even conventional dry landfills can benefit from better techniques and materials, says civil engineer Robert E. Landreth, chief of landfill technology at EPA's Risk Reduction Engineering Laboratory in Cincinnati. For example, instead of burying each day's accumulation of wastes under several inches of soil, landfill managers can preserve space by blanketing wastes overnight with synthetic covers, such as a layer of foam. The next day, bulldozers break the foam moisture barrier before the next load of waste arrives.

Unlike conventional landfills, which permanently segregate daily garbage deposits in dirt-shielded cells, these allow the interred wastes to mix into a more homogeneous mass and accelerate decomposition, says Landreth.

To determine decomposition rates in full-scale wet and dry landfills, University of Wisconsin civil engineer Robert Ham plans to analyze working landfills in Florida, New York, Pennsylvania and Wisconsin. The Wisconsin landfill will include experimental wet and dry cells; the others will have sections covered with sand, allowing precipitation to flow into the garbage. Results of his work won't be known until the mid-1990s.

Though wet landfills must be monitored more carefully than dry ones, Ham says they can be cost-effective in the long run by shortening the decay period and thus reducing the time required for monitoring. Before landfill managers recognized the extent of the leakage problem, "you'd finish up the landfill, cover it and walk away from it," he says. But those days are over. "What we're talking about is getting the bulk of decomposition to occur more rapidly so we don't have exposure to problems many years in the future." □