RECYCLING HUMAN WASTE:

Fertile Ground or Toxic Legacy?

Recycling human waste isn't like recycling newspapers. The use of "night soil" on cropland is ancient, but modern sewage and farming systems have greatly complicated the risks of using our most obvious fertilizer.

by Gary Gardner

In 1997 the U.S. Environmental Protection Agency (EPA) approved a plan that takes sewage recycling to new and bizarre levels. Wastewater from cleanup of the Lowry Landfill near Denver—a Superfund site contaminated with chemicals and heavy metals, including nuclear waste—was to be dumped into local sewers and treated at the local sewage treatment plant. The plant would mix the toxic brew with ordinary sewage, process it, and release the resulting products: water to the South Platte River, and sludge to nearby farms for use as fertilizer. The program was part of the agency's attempt to recycle a greater share of U.S. sludge to "beneficial uses."

The plan, which drew howls of local protest, is an extreme example of a growing trend: the use of human waste to fertilize farms, in spite of unresolved questions about the practice's risks. As greater quantities of human waste are produced, and as traditional dumping areas are placed off-limits or become increasingly costly, policymakers have resorted to this ancient strategy to dispose of the nutrient-rich material. But because modern waste flows are dirtier than those of centuries past, capturing the benefits of reuse with minimal risk is a growing challenge.

The experience of modern sludge reuse has the qualities of a fable, with valuable lessons for the larger question of recycling. Global materials use is far greater than the planet can sustain; Mathis Wackernagel and William Rees of the University of British Columbia have shown that today's economies already consume one third more resources and eco-services than nature can deliver sustainably. Reducing our "ecological footprint" will therefore require a far greater level of materials *reuse.* But as recycling moves well beyond newspapers and aluminum cans, it is important to distinguish between beneficial recycling—the return of materials to advantageous and environmentally benign uses—and careless reuse, which is sometimes little more than dumping under a green label. The lessons of this fable are important for industrialized nations active in recycling human waste. They are even more timely for the many developing country cities that are busy planning and designing sanitation systems for the next century.

An Ancient Practice

Recycling human waste has a long and noble history. Chinese agriculture, for example, was sustained for thousands of years by the "night soil" collected from cities and rural villages. In his classic study *Farmers of Forty Centuries*, agricultural historian F.H. King reports that farmers would build roadside outhouses and post advertising to entice travelers to use them, so desired was the excrement as a supplemental source of nutrients and organic matter. The city of Shanghai commonly sold the right to collect the city's night soil for sale in the countryside, a concession that in 1908 brought the equivalent of $31,000 in gold to municipal coffers.

Organic recycling was less common outside of Asia, but eventually became more widely practiced as burgeoning cities scrambled to get rid of their waste. By the mid-nineteenth century, as some European cities passed the one million mark in population, sewage was collected by scavengers and delivered to nearby "sewage farms" for use as fertilizer. The practice soon spread to cities in the United States, Australia, and Mexico. Indeed, by the early twentieth century, with sewers commonly in use in more developed countries, land application of sewage was the sole method of disposal in many metropolitan areas.

In this pre-modern era, and in many developing countries today, the chief health risk from sewage came from its pathogen content. Untreated sewage is alive with bacteria, viruses, and parasites, which can spread to people through water supplies, food fertilized with waste, or direct contact. Open-air sewage flows facilitate the spread of sickness, prompting outbreaks of cholera and other infectious diseases, as occurred in urbanized countries in centuries past, and continues to occur in developing countries today. The spouse of a Worldwatch researcher recalls the terrible choice faced by villagers in her native South Korea in the 1960's: use raw human waste in rice paddies to ensure higher production—but at the cost of widespread sickness, as parasites from feces became intestinal worms in nearly all villagers—or protect the village from the health threat of human waste and accept lower yields. Pathogens are a serious and even deadly threat, but they are relatively short-lived, eventually breaking down in the soils to which they are applied.

In this century, underground sewers became increasingly common, and some were eventually connected to treatment plants. Used together, the two technologies greatly reduced the pathogen menace. But new contaminants surfaced in many cities. As industries hooked up to public sewers, their waste flows—often containing toxic chemicals and heavy metals—mixed with human waste. Sewage treatment

NEIGHBORHOOD SEWAGE TREATMENT FACILITY

A creative approach to sewage recycling, conceived by Living Technologies of Vermont, would place a small-scale treatment facility right in a neighborhood. Sewage could be treated locally and inexpensively, in a small, contained loop that would produce clean water for use on neighborhood gardens.

processes, while somewhat effective at killing pathogens, did not eliminate these other contaminants; instead, the pollutants simply accumulated in the sludge. But because most sludge was destined for disposal at a landfill, in an incinerator, or even on the ocean bottom, authorities saw little reason to worry about these substances.

Over the past quarter century, however, several developments have renewed interest in recycling human waste to land. Urban growth and an increasingly sewered population have concentrated more and more human waste in urban areas. Indeed, U.S. sewage sludge has doubled in quantity since 1972, even though population has grown by only 25 percent, largely because of the 1972 Clean Water Act, which funded a boom in sewer construction. At the same time, waste disposal sites are less available, or more expensive. Ocean dumping of sewage sludge was outlawed in the United States in 1992, and will be illegal in Europe after 1998. Incineration is costly, and landfills leak greenhouse gases—globally, landfills account for some ten percent of the world's human-origin emissions of methane, an exceptionally potent greenhouse gas.

Nearly all of the tens of thousands of chemicals and metals flowing through modern economies—including PCBs, pesticides, dioxins, heavy metals, asbestos, petroleum products and industrial solvents—are potentially a part of sewage flows.

Meanwhile, many arid nations have begun to tap wastewater for irrigation as they struggle to deal with chronic water scarcity. And the use of manufactured fertilizers—the technology that has largely undercut the practice of reapplying wastes to soils—has been blamed for a variety of pollution ills, from unhealthy nitrate levels in drinking water to algae blooms that rob fish and other aquatic species of oxygen.

All of these problems are related to the snipping open of the "organic loop," which ended the circular flow of human waste from people to farms, then back to people in the form of food. The natural response to resolving these problems was to re-connect the loop by once again recycling human (and other organic) waste. By the early 1990s, fully a third of the sewage sludge generated in Europe, and more than a quarter of that produced in the United States, was being applied to farmland. And a joint World Bank-U.N. Development Programme study estimated in 1985 that some 80 percent of the wastewater in developing countries was used for permanent or seasonal irrigation. Most of this irrigation flow would have been raw sewage, as even today less than 10 percent of sewered cities in developing countries are connected to treatment plants.

Read the Label

Reconnecting a materials loop can happen in many ways, some more harmful than others. Ideally, recycling would imitate nature's cycling process, which is more efficient and benign than any process created by humans, with all materials productively reused. But recycling can be difficult in modern industrial economies, which mix materials in combinations and concentrations not normally found in nature. Wood pulp, for example, can be processed into paper using a solution of caustic soda and sodium sulfide, with sulfate remaining in the final paper product. Paper may then be dyed or coated or may have adhesive material attached to it. By the end of its useful life, paper may contain several foreign materials that complicate its return to the soils that nourish tree roots.

Even for simple flows of organic material like that of human waste, industrial economies have complicated the prospects for reuse. On the journey from toilet to treatment plant, excreta mixes with toxic chemicals and heavy metals, which are poured down household drains and leached from household plumbing, or dumped into sewers by industry. Indeed, nearly all of the tens of thousands of chemicals and metals flowing through modern economies—including PCBs, pesticides, dioxins, heavy metals, asbestos, petroleum products and industrial solvents—are potentially a part of sewage flows. Some of these materials degrade quickly with no harm to the environment, while others persist for decades or even centuries; some soils in Italy, for example, still contain lead leached from the pipes of ancient Rome. Natural cycling tends to keep potentially polluting materials spread thin. Human economies, however, often distill and concentrate harmful pollutants in our waste streams. Depending on the levels of concentration, returning these wastes to farmland can be more dangerous than beneficial.

How much waste is too much is hotly debated in industrialized countries, especially the United States. Controversy there centers on rules set down in 1993 by the EPA, known as the "Part 503" sludge standards for their place in the Code of Federal Regulations. Years in the making, and the product of an extensive risk assessment process, the rules are nevertheless criticized by citizens groups and at least one academic institute for being insufficiently cautious. The ongoing debate over the standards highlights several issues that are important for recycling in general.

First, it is crucial to document the levels of potentially harmful extraneous matter in material destined for recycling, and the quantities in which they are present. The average makeup of sewage sludge in the United States is generally known, thanks to a National Sewage Sludge Survey undertaken by the EPA in 1988. But because sludge contents differ from place to place—or even from day to day in the same place—the makeup of a particular batch of land-applied sludge is too often unknown. For example, the survey found toxic chemicals were present at such low levels nationally that the EPA decided not to regulate them. Despite the low national average, high levels of toxic chemicals have been found in the sludge of towns with industries that use those particular chemicals. The 503 rules would not prevent such highly contaminated sludge from being used on cropland.

Nor do the rules set standards for radioactivity, or require testing for it—which explains how nuclear waste-tainted sludge from the Lowry landfill could pass muster for use on cropland. A 1994 report by the U.S. General Accounting Office (GAO) found that between 1983 and 1991, nine cases of radioactive contamination of sewage treatment plants were found—even without a systematic inspection regime in place. Indeed, only 15 of 1100 hospitals, manufacturers, and other sites that discharge radioactive material to sewers had been inspected by the Nuclear Regulatory Commission (NRC), at the time of the GAO report. And of the treatment plants surveyed, most had no idea that radioactive material could be part of their inflow, and did not test for it. Neither the EPA nor the NRC know how much material is thrown into sewers, nor how great a threat this material poses to contamination of sewage sludge.

The EPA is quick to point out that the presence of contaminants in U.S. sewage flows is lower than it was two decades ago, because many industries now "pretreat" their waste to reduce the levels of contaminants that enter sewers. Seven eastern U.S. cities, for example, saw metals contamination of sewage drop by an average 35 percent between 1988 and 1996. And those who dump large amounts of contaminants can likely be identified, according to the EPA, once authorities are alerted to the problem and place monitors in sewers. Nevertheless, the rules would do little to prevent dangerous one-time dumping, or to detect it when it occurs.

Second, it is important to understand the hazards posed by contaminants in recycled material. The EPA asserts that the risk assessment used to develop the 503 rules was sufficiently conservative to protect the public. But Cornell University's Waste Management Institute charges that the assessment was not cautious enough, and that the full effects of sludge on the environment and on humans are not understood. Cornell researcher Murray McBride says that too little is known about the long-term behavior of metals in sludge-applied soils, for example, and that heavy metals could eventually be freed up and absorbed by crops. This "time bomb" theory postulates that as organic matter in sludge breaks down over time, the bonds that keep metals from travelling—either down into groundwater or up into crops—will be weakened. Metals that are largely immobile in the short run, he asserts, could well be found in our food and our drinking water in the long run. Other scientists, including long-time sludge researcher Dr. Rufus Chaney of the U.S. Department of Agriculture, argue that enough long-term studies on sludge have been done to show that no sludge "time bomb" exists. But given the stakes involved—human health and increasingly precious cropland—the burden of proof lies with those who assert that the risk is acceptable.

Likewise, our understanding of the threat posed by toxic chemicals—which are entirely unregulated under 503—is not well understood. Chemicals that persist in the environment, including the pcbs and dioxins found in sewage sludge, are now suspected of mimicking hormones and causing reproductive abnormalities in humans and wildlife, even when their presence is so minute it must be measured in parts per *trillion*. EPA Administrator Carol Browner warned in September 1997 that rising rates of several cancers in children—testicular cancer is up 70 percent in the past two decades—may be connected to the omnipresence of chemicals in the U.S. economy since mid-century. Prudence would counsel against allowing such chemicals to become part of the nation's drinking water or food supply.

Finally, even if all parties were to agree on recycling standards and their coverage, the consensus would mean little if the rules go unenforced. On this question, even many defenders of the 503 regulations acknowledge the need for improvement. The 503 rules were written to be "self-implementing," meaning that treatment plant operators are responsible for testing sludge for regulated pollutants, and farmers keep track of low-grade sludge applications ("high quality" sludge requires no tracking whatsoever). Testing of sludge is required monthly where the largest quantities are produced, and as seldom as once a year for the smallest quantities. Such infrequent monitoring is a poor defense against indiscriminate dumping into sewers. And stored material is not regulated, even though pathogens can re-generate in sludges that are held aside for the winter, or until after a field is harvested.

While the standards and regulations are still hotly debated, and because the stakes are high, caution should be the watchword. Until the risks are better understood, sludge might best be land applied only to non-agricultural land. The material has been successfully used, for example, to "bio-remediate" and restore degraded lands, including Superfund sites and strip-mined areas. It can also be used to green highway meridians and golf courses. Beyond limiting its use, enforcement needs to be stepped up to ensure that today's standards are being honored. And stricter pretreatment programs should be instituted to cover a broader range of polluters, and to enforce a lower level of dumping. The cleaner the sludge, the more likely its organic richness could eventually be applied to cropland.

The Wrong Tool for the Job

Debating acceptable levels of contaminants, however, begs the fundamental question of whether pollutants should be in sludge at all. The question is largely avoided in Europe and the United States—where the focus is on finding acceptable pollution standards—because industrial nations are wedded to technologies designed for *disposal*, rather than *recycling*. On several counts, today's system of flush toilets, sewers, and treatment plants are inferior technologies for recycling human waste.

Sewers, as noted, commonly serve residences and industry together, a practice that often contaminates organic matter with heavy metals or toxic chemicals. While many of these impurities could in theory be removed at the treatment plant, the process would be very expensive. From a recycling perspective, it would be far better to prevent human waste from mixing with other wastes in the first place. Segregation of waste streams could be achieved by using separate sewers for human and other wastes, by treatment of industrial waste at the factory, or by treatment of human waste in residences or office buildings.

In addition, treatment plants are designed to recycle water, but not sludge. Treatment essentially involves removing a concoction of benign elements (organic matter and nutrients) and nasty ones (pathogens, toxic chemicals, and heavy metals) from the water that carries them. The process yields relatively clean (but non-potable) water, and sludge, a muck that is thick with elements removed from the water. Thus, the cleaner the water produced, the dirtier the sludge. As long as sludge was destined for burial or incineration, contaminant levels were ignored. But when applied to land, of course, the pollution content matters a great deal.

Moreover, treatment plants often eliminate some of the material that should be recycled. The digestion process—the "stomach" of a treatment plant where bacteria break down organic matter and kill most pathogens—converts part of the sewage's nitrogen content to a gaseous form, which is then lost to the atmosphere. Nitrogen is the single most important nutrient for plant growth; eliminating any of it makes little sense from a recycling perspective. Indeed, using a digester to recycle sewage is akin to firing up an incinerator to recycle newspapers.

Finally, conventional treatment methods (with the exception of disinfection, a high level of treatment that is unaffordable in many developing countries) reduce pathogens by too little for safe reuse in agriculture. A conventional treatment plant can reduce the number of fecal coliforms in a milliliter of water from 100 million to 1 million, a 99 percent reduction—but not enough for use on crops. For unrestricted irrigation use, the World Health Organization recommends a fecal coliform level a thousand times lower—no greater than 1,000 per milliliter.

Some technologies modify conventional sewage treatment to produce a product that gets closer to a safe recyclable. One such process is called advance alkaline stabilization, and is used by an Ohio-based company called N-VIRO. The company mixes roughly equal parts of sewage sludge and alkaline material such as cement kiln dust to produce a sludge product called "N-VIRO soil." The alkaline dust raises the pH level, which prevents most of the sludge's metals from leaching or being taken up by plants. In addition, the dust pasteurizes the sludge, killing pathogens so thoroughly that it eliminates the need for digestion. And skipping the nutrient-hungry and methane-belching digestion process yields more recycled material with fewer emissions of greenhouse gases. Moreover, because digestion is typically capital-intensive, its removal makes sewage treatment more affordable. Middlesex County in New Jersey, for example, opted for the N-VIRO process over a conventional plant and saved 2 million dollars annually in operating costs.

While the N-VIRO process aims to reconnect the organic loop safely, it is still used in conjunction with some disposal technologies, such as sewers that mix domestic and industrial wastes. To this degree, "N-VIRO soil" is riskier than waste processed entirely with recycling technologies. The N-VIRO process does not eliminate or neutralize toxic chemicals, for example, and some scientists worry that immobilized metals could be freed in soils with extremely high pH levels, although such conditions are rare. The process is most promising, therefore, where contaminant levels are very low, both in the sludge and in the kiln dust that is mixed with it.

Rethinking Recycling

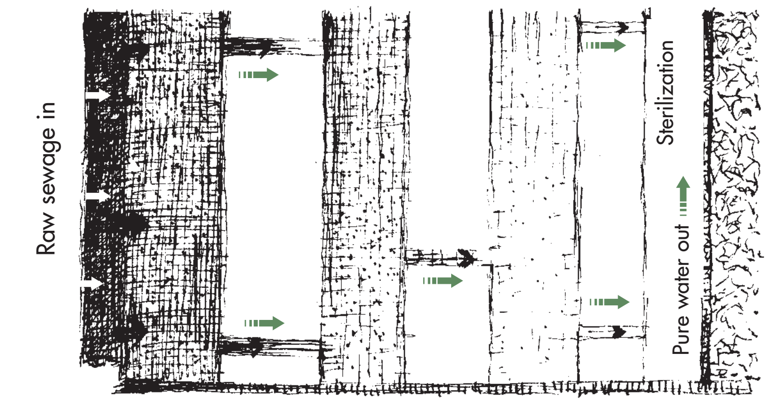
The emerging recycling lesson is this: the more that reuse of human waste relies on conventional *disposal* technologies, the less likely that such reuse will be benign recycling. This is bad news for cities with heavy investments in disposal systems; they may require extensive adjustments to achieve environmentally benign recycling. It is good news, however, for cities that have not yet committed to a particular system of sanitation, and for cities that face extensive rehabilitation of old systems. These later-developing cities have a chance to "leapfrog" ahead to alternative technologies designed for recycling—and to save scarce investment funds in the process.

Common to many alternative systems is the separation of human waste from other contaminants. One way of doing this is to treat industrial wastes at the source, so that they never enter the public sewer system. To some degree, this is already done at many factories and plants through the "pretreatment" processes that partially remove pollutants from waste flows. But complete treatment is possible as well, as demonstrated through the systems developed by Living Technologies of Vermont. Modeled on nature's cleansing processes, the systems use plants, microorganisms, and fish, in combination with solar energy, to progressively treat industrial wastes in a series of pools and constructed wetlands. The firm has found a robust market for these facilities, with 20 projects built or under construction since 1992 at businesses and institutions as diverse as the M&M/Mars Company in Brazil and Oberlin College in Ohio. The systems require space, of course, which may be in short supply at some facilities. They also need maintenance by a trained technician.

The people at Living Technologies have other plans for waste treatment, including neighborhood-level "sewage walls" that would run the length of a residential block, separating street from sidewalk. (See illustrations.) The wide, low walls slope toward the sidewalk and contain four terraces filled with plants and capped with glass. Wastewater from the street's houses is filtered progressively through the terraces until treated and ready for use on gardens or other areas. Not yet in operation, the design nevertheless offers a vision of how human waste might be recycled cleanly and locally.

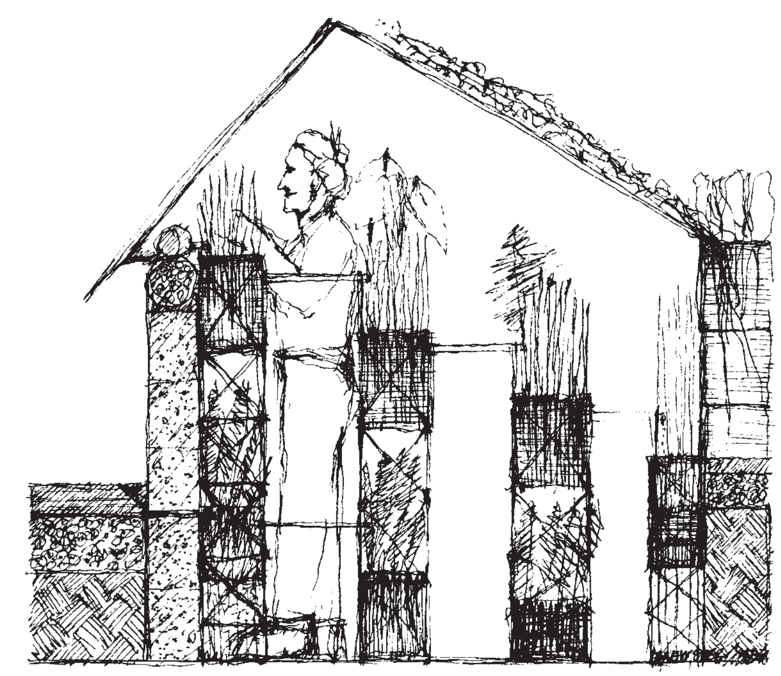
Another separation strategy is to treat domestic wastes at the source.

INSIDE A SOLAR SEWAGE WALL



The neighborhood sewage wall, an alternative idea for sewage treatment, would channel sewage through a series of terraced planters that progressively filter and purify the waste. Each terrace would contain the plants and bacteria best suited for the various stages of treatment. The resulting effluent could be used on local gardens, and the plants could be harvested and composted.

ILLUSTRATIONS ABOVE, BELOW, AND ON PAGE 29, BY ELISE BREWSTER, FROM *FROM ECO-CITIES TO LIVING MACHINES: PRINCIPALS OF ECOLOGICAL DESIGN* BY NANCY JACK TODD AND JOHN TODD. © 1994 BY NANCY JACK TODD AND JOHN TODD. USED BY ARRANGEMENT WITH NORTH ATLANTIC BOOKS, BERKELEY, CA.



Household treatment has the advantage of isolating human waste from home-grown chemicals and metals: detergents, soaps, and cleaning solvents, for example, and copper and other metals that leach from plumbing. Composting toilets are one viable on-site recycling technology. They look like standard flush models (without the water tank, as most use no water) and can hold up to several years' worth of excreta. They require some maintenance, including occasional additions of bulking material such as popcorn (to create the air pockets needed to support microbes) and periodic inspection of the compost itself, but the burden is minimal. These systems create a fertilizing product that can be applied to home gardens or, where economically feasible, collected and sold to farmers. They are not yet widely used in homes because plumbing codes often discriminate against them, and because they are expensive ($1000 to $6000 in the United States). They are also culturally unattractive in many societies accustomed to flush toilets. Still, the municipality of Tanum, Sweden is successfully converting homes to composting technology as part of its bid to become free of flush toilets.

In developing countries, a new and promising option for processing domestic waste is a series of simple technologies developed in Mexico and known collectively by their Spanish acronym, SIRDO. SIRDO systems use "double-vault" waste treatment; one chamber collects current wastes while the other is closed for several months as previously deposited material composts. Solar heating and bacteria transform wastes and other carbon matter into a safe and odorless "biofertilizer" that is sold to nearby farms.

SIRDO technology is used in diverse ways. Some designs are "dry," requiring no water—and no sewage infrastructure—for their operation. Dry units are self-contained structures that are detached from a house and serve one or two families. They compost household organic matter together with human waste, thereby easing pressure on both landfills and sewage treatment plants. "Wet" SIRDO units are neighborhood-level miniplants that biologically process the wastes of up to 1,000 people, operating in conjunction with existing flush toilets and local sewer lines. "Wet" systems separate greywater from solids and percolate it through a bed of sand and gravel until it is purified enough to reuse on gardens, or to irrigate nonfood crops.

These alternative technologies also have substantial side benefits. To the extent that they recycle water, or do not require it, they are especially attractive for arid areas as a source of water savings. Flush toilets have been shown to account for 20–40 percent of the residential water use in industrial countries; the proportion would undoubtedly be higher in developing countries. With the population of "water-stressed" countries expected to more than triple by 2025, any technology that can reduce water demand merits serious consideration.

Moreover, many of these systems require less investment—only one seventh as much, and perhaps substantially less—than is needed for conventional sewer and treatment plant infrastructure. The World Bank estimates that developing countries will need 600 *billion* dollars' worth of water and sewer investments in the coming decades; inexpensive and ecologically sound alternatives could greatly reduce this budgetary burden. The burden might even be avoided entirely, because some of these technologies actually pay for themselves. A cost-benefit analysis of the SIRDO technology undertaken by the U.S.-based National Wildlife Federation (NWF) found that the start-up costs can be recovered within 2 to 20 years, depending on the model, through the sale of the fertilizer they generated. Indeed, fertilizer sales are sufficient to boost incomes as well: families earn some $30 to 60 dollars annually from their toilets, a modest but meaningful income supplement for people living on the economic margin.

A Material World

The appeal of these alternative waste technologies is that they recycle in a regenerative loop as nature does. Natural cycling systems tend to eliminate harmful materials that could pollute their own loops, as a wetland does when it removes nutrients from overenriched waters. Even a conventional engineer, if charged with designing from scratch a recycling system for human waste, would hardly choose to introduce extraneous metals or toxic chemicals to the mix. The verity that "nature knows no waste" is true not only because all materials are recycled, but also because they are cycled usefully.

Nature-centered recycling is a compelling option for the reuse of materials—from human waste to sawdust—as societies struggle to eliminate the flow of resources straight to the dump. The struggle is herculean: the Organisation for Economic Cooperation and Development recently adopted as a long-range goal a ten-fold reduction in materials flows in industrialized countries. This vision will certainly require high rates of recycling, especially for material like human waste for which the "reduce" and "reuse" options (in the troika of "reduce, reuse, recycle") are not viable strategies. As communities choose recycling—and as they choose to make that recycling a clean replica of nature—they will move a large step closer to sustainable management of our planet's resources.

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