

Toward Sustainable Sanitation

Editors:

Robert Goodland, Laura Orlando and Jeff Anhang

**Toward
Sustainable
Sanitation:
What is Sustainability
in Sanitation?**

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Foreword

Robert Goodland and Laura Orlando

Sanitation is practiced to prevent disease and promote health. Practiced successfully, the result would be healthy people and a healthy environment. Education, behavioral changes, access to clean water, solid and industrial waste management, and the safe disposition of excreta all impact the efficacy of sanitation. This is a complex issue. A good resolution cannot be reached if any component is ignored. The concern of this book is the development of sustainable sanitation, especially the sustainable management of human excreta.

The sustainable management of human excreta has hardly been considered, much less enacted, by decision and policymakers. The purpose of this book is to introduce some parameters of sustainability in this crucial area of public and environmental health. Sustainable sanitation is not a matter of rich or poor, though the urgency for it is more obvious in the Global South, where 65% of the people have no sanitation facilities and diarrheal diseases cause 3 million deaths per year.

The technologies preferred by governments and development agencies to improve access are sewers and latrines. Sewers, institutionalized by the industrial nations of the world, are causing little understood though vast health problems wherever they exist. Latrines are the presumed "adequate sanitation" for less-industrialized nations. Abby Rockefeller and Robert Goodland, authors of the introductory chapter, "What is Environmental Sustainability in Sanitation," say, "From the point of view of environmental sustainability, any on-site sanitation system is better than central collection and treatment." The overall environmental and therefore human health damage caused by latrines and on-site septic systems is less than that caused by sewers, but are they sustainable?

The contributing authors to this book are scholars, ecologists, development specialists, and practitioners, each sharing his or her vision of sustainable sanitation. Robert Goodland and Abby Rockefeller set the

tone in their paper, "What is Environmental Sustainability in Sanitation." They close with four policy suggestions: do not sewer, get off sewers, promote on-site technologies, and price water correctly. Rockefeller discusses the history of sanitation in her article "Civilization and Sludge: Notes on the History of the Management of Human Excreta." Gary Gardner makes a case for returning nutrients in organic matter to farm soils — "closing the organic loop" — as a critical step toward sustainability for the world's cities and national economies. Laura Orlando argues against the "beneficial use" of sewage sludge, saying it is toxic waste and should be treated as such. Future trends in sustainable sanitation hinge on policy shifts and innovative, demand driven programs. Rockefeller outlines what a sustainable sanitation policy might look like. Orlando gives us a look at an entrepreneurial composting toilet project in Mexico. In another paper, she explores the gap between demand and the provision of services. Stephen Latham concludes the section with an essay on microcredit, water supply, and sanitation.

Preface

Kristalina Georgieva

*"Nothing has really changed in urban sanitation in the last 150 years or so; it is one of the least technologically advanced fields..."** Therefore, the goal of this publication — to set out new, environmentally sustainable, approaches to sanitation — is most welcome.

Ecological sanitation solutions, as promoted by the authors, make inherent sense, especially in the many water-stressed and resource-poor regions of the world. As the world has an annual deficit of over 160 billion tons of water, and as industrial demand for water diverts water away from irrigation, the savings of 30-40% in consumption of average daily clean water, achievable through sustainable sanitation, is a huge benefit. At the same time, sustainable sanitation can improve poor soils and provide valuable nutrients for food production.

As presented by the authors, economics favor this approach, but we need more analytical work. We need to show the high and intensifying environmental costs, still mainly externalized, of traditional sanitation. We also need to deepen our understanding of the social and cultural factors that determine the success or failure of sanitation systems. In addition, we need to explore why orthodox water and sanitation professionals still have so little understanding and acceptance of sustainable sanitation.

This book addresses some of the main concerns of emerging environmental strategy at organizations such as the World Bank, importantly poverty alleviation, assisted by sustainable, health-promoting sanitation systems. Implementation of more sustainable solutions would better take into account long-term environmental considerations, as well as community-driven approaches to development.

* Professor Doug Webster, Stanford University

Introduction

Abby A. Rockefeller and Robert Goodland

What is Environmental Sustainability in Sanitation?

1. The Unsustainability of Sewage

For the reasons outlined below, the present approach to the disposal of human wastes — central collection and treatment of sewage — is unsustainable. Nevertheless, the fever to sewer the globe seems to be growing. For the sake of environmental sustainability, we must stop mixing human excreta with drinking water, then collecting and further worsening this mixture with industrial and non-point source wastes, then "treating" the mixture, then polluting water, air, or soil by efforts to dispose of the poisonous sludge created by the treatment process. Such practices may have appeared affordable decades ago. Now population densities, urbanization, and pervasive pollution of nearly all water bodies show the unsustainability of the system. Though U.S. sewerage construction has been, until the last few years, the largest construction grants program in U.S. history, this expenditure of billions of dollars does not begin to reflect the full environmental and financial cost to society of this unsustainable effort to manage waste.

This paper calls for a fundamental rethinking of the human waste problem if the world is to reverse its decline from the current unsustainable sanitation practices to approaches that would promote environmental sustainability.

2. Economic Costs of Sewerage

In central collection and treatment of sewage, 80%-90% of the total costs goes to transportation (e.g., laying of pipes: water is sometimes conveyed several hundred kilometers from water supply to users to sewage treatment plant), land acquisition for reservoirs, and involuntary resettlement of people to make room for these reservoirs. About 10%-

20% of the overall cost is in the treatment processes. Energy costs for both pumping and treatment are enormous. House- to-sewer connections, trunk lines, and collectors leading to peri-urban sewage treatment facilities are increasingly expensive for affluent Organization for Economic Cooperation & Development (OECD) cities. Initial construction costs alone for sewerage in OECD cities are about \$50,000 per household. This does not include organization and management (O&M) or hookups from sewer main to each house. Even if the costs are half that in Less Developed Country (LDC) cities, it is clearly prohibitive for poor nations. Figure 1 shows that flush toilets use 40% of the total residential demand for municipal water. If we stopped using water to transport human excreta, reservoirs could be half as large and therefore much less costly. When cities were fewer and smaller and population densities were lower, the cost of collecting and storing water for such purposes seemed, in financial terms, affordable. That era has long gone.

Figure 1: Recommended Minimum Water Requirements for Residential Use (From Gleick, 1996)	
Purpose	Liters/person/day
Drinking	5
Cooking	10
Bathing	1
Sanitation	20
Total	36

If the recommended minimum water use for LDC cities of approximately 36 liters per person as suggested in Figure 1 is disaggregated into its four main components, it is evident that flushing toilets is the largest single category of domestic water use and the only one with significant room for reduction. (The average OECD sanitation use is 40 liters per day and all other uses, except drinking, are comparably greater.) There is no room for conservation of drinking water; virtually none in cooking; some in the bathing category through,

for example, water-conserving shower and faucet fixtures. Sanitation using flush toilets has, by contrast, substantial scope for water conservation; and sustainability demands that it be stringently reduced, preferably to zero. That water for flushing toilets can be reduced to zero has been demonstrated successfully by the use of composting toilets at public facilities and residences in the U.S., Sweden, and South Korea (to name a few countries where this technology has been seriously applied), where a household of four saves 40,000 gallons per year and a public facility serving 70,000 people saves 350,000 gallons per year.

Sweden's entire province of Tanum is converting to composting toilets in order to reduce pollution of beaches and damage to fisheries, and because it is cheaper than conventional sewerage according to Schoenbeck (1996). Other provinces are following that lead. Tanum has found that their composting method reduces nitrogen and phosphorus pollution 90-95% below the levels reached by conventional sewage treatment plants.

3. Diversion of Scarce Water to Sewage

Clean water, an increasingly scarce commodity, should be allocated to its most productive and sustainable uses. From the point of view of the availability of water alone, most cities do not have enough fresh water to justify continuing with central collection sewage systems. Transportation of wastes by water requires huge amounts of water just to keep the wastes moving in the pipes. This has been demonstrated in a number of U.S. cities where many sewer lines plugged up after water conservation programs introduced the use of 1.6 gallon toilets instead of the usual 3-5 gallon flush. It is often now recommended that people with such low-water toilets flush twice or thrice per use.

The situation in many areas is so severe that some countries are having to seek alternative sources of water. In Hong Kong, sea water is now used for a parallel sanitation system. But, since building a parallel system of distribution for sea water would be too expensive for most older cities, brine may be pumped into existing fresh water systems. However, a likely danger of such a choice would be contamination of

fresh groundwater supplies by exfiltration from leaking sewerage. This would further degrade groundwater — the world's prime source of fresh water. Further, current infrastructure for transporting fresh groundwater to people for drinking, cooking, and washing would be rendered unusable. Fresh water would then have to be supplied by truck or containers or piped from even greater distances — clearly an expensive proposition.

4. Water Leakage

Maintenance of water supply and sewage collection infrastructure, even in affluent OECD cities, entails increasingly onerous costs, since many municipal sewerage systems are in advanced states of decay. Sewage leakage into water supplies and into groundwater is increasingly common worldwide. Municipalities are uncertain where financing for rehabilitation of the pipes can be found. If the situation is desperate for OECD cities, the problem of funding the rehabilitation of leaky water supply and sewer systems is orders of magnitude worse for LDC cities, which by definition have less money to spend and where human populations are in many cases already larger and growing faster.

5. The Failure of Conventional Sewage

The enormous expense entailed in the treatment effort to extract clean water from sewage is a wasted cost, since this vast expenditure of public funds has not — and cannot — provide environmentally sustainable sanitation. That is, it cannot solve the multiple problems caused by this form of water pollution. As a system, it cannot clean the water we have chosen to pollute without introducing more complex and environmentally unsustainable effects. The reason lies in the flawed concept of the separation technology itself: it is a virtual impossibility to clean water that has been used to transport human wastes. The inevitable products of this system are first more or less degraded water, and second more or less toxic sludge. The more advanced the treatment of the sewage (i.e., the more successful the separation of the pollutants from the water), the more sludge will be produced and the worse — the more unpredictable and dangerous — the sludge will be.

The problems associated with central collection and treatment of sewage—pipe laying, leakage and loss of water from sewers, the costs and the failure of ever more elaborate forms of treatment, and finally, the creation of sludge — these are all endemic to central collection and treatment. Each stage only leads in its turn to more unsolvable problems as the primary problem is merely moved from one place to another, and from one form to another. The result of this attempt to manage human and industrial waste streams is that the end product, sludge, is so replete with pathogens, organic and inorganic toxins, and a virtually unknowable range of chemicals, that it is classified as a hazardous material requiring strict regulation for transportation and disposal.

6. What to Do With Sludge

Ocean disposal of sewage sludge — sludge which had just been removed from water — was, in coastal cities of the U.S., standard practice until 1992. Though clearly unsustainable, it was nevertheless only after strong public protest that the U.S. Congress passed a law in 1988, to be effective in 1992, banning ocean dumping. But the alternatives are also unsustainable. Landfilling, long the convention in cities far from oceans, pollutes groundwater. Incineration, in addition to pumping toxic chemicals into the air, generates dioxins that can be lethal in only parts per billion.

Both landfilling and incineration were employed for a number of years until environmental objections intensified. To fill the vacuum caused by this opposition, US Environmental Protection Agency (EPA) adopted the idea of disposing of the sludge by spreading it — as a "fertilizer" — on agricultural land. Sludge's four main categories of pollutants — nutrients, pathogens, toxic organics and heavy metals — behave differently and cannot be managed by a single kind of treatment. Land application was implemented in Sweden in the early 1980s with disastrous results, which the US EPA seems to be ignoring. Such a practice must lead to accumulation in living tissues of heavy metals and persistent organic chemicals: first they accumulate in the soil, then in decomposer microbes and soil-conditioning invertebrates. Other life

forms are damaged as thousands of non-biocompatible substances move up the food chain. The toxic effect on crops, as well as on the consumers of such crops, is creating risks for the future.

Despite such risks, governments and environmental protection agencies the world over are forcefully promoting land application of sludge — because it is the cheapest form of disposal. It is misguided of regulators to try to persuade the world that sludge, though undisposable, is recyclable — suitable for "beneficial reuse," as the phrase now goes. In a sustainable world, nothing can be "disposed of," but this doesn't mean that everything now in human use can be recycled. What cannot be recycled is not sustainable and should not be produced. Sludge is one such material.

7. Solutions

First, we must stop debasing intrinsically valuable resources such as clean water and human excreta by combining them with all other "wastes" that can be made to fit down the drain, where they result in unusable and undisposable sludge. Governments must come to understand what solving the problems now caused by these "wastes" really means in terms of environmental sustainability. Pollution prevention, sewage reduction, separation at the source, and water conservation should be maximized.

Only thorough source separation can make possible the creation of products — out of "wastes" — that are environmentally benign (e.g., organic products that are compatible with normal metabolic processes). Materials that are not life-compatible, especially heavy metals, toxic chemicals, and toxic organic materials used in industrial processes, must be retained in closed-loops and reused within the industries from which they come. Industry must be held accountable for the appropriate management of its own byproducts. This means industry must not be allowed to abdicate environmental accountability by using sewers as a cheap dump. It is society in the form of human beings and their communities who now pay the financial and health costs of subsidizing this cheap garbage disposal for industries.

By converting "waste" materials to usable products at the point of generation, both the economic and the environmental costs of central treatment can be avoided. Obliging industry to participate in source separation programs moves responsibility — including the fiscal burden — back to where it belongs. Human excreta and clean water can then indeed be reclaimed for further beneficial use.

8. Policy Suggestions

Clearly in such a complex field there are no panaceas. There are, however, three general principles that would revolutionize the management of this global predicament. The principles should be tailored to local conditions such as climate and geology. All are applicable in most cities, and implementing even one of them would greatly alleviate current unsustainable practices. All are preferable to conventional trends. This paper suggests they be evaluated in view of the unsustainability of conventional practices.

The three general principles are first, that society should institute a policy of sewer avoidance (i.e., stay off or get off sewers). Second, low cost, on-site resource recycling technologies, such as composting toilets, which avoid polluting water and preclude wasting resources, should be promoted. Third, water must be priced right.

8.1 Sewer Avoidance

A policy to avoid sewers has two parts. First, in the thousands of cities, towns, and communities around the world now served by one kind of on-site sanitation system or another (e.g., pit latrines, cesspools, and septic fields), just don't sewer. Instead, use development funds to install on-site remediation technologies, of which there are a number already on the market superior to septic systems in their ability to accomplish pollution prevention or abatement. The advantages of such a program are great:

- development of communities is not bound to the rigid grid of sewer lines;
- pollution problems can be dealt with piecemeal — where they really exist, and first where they are worst;
- capital as well as maintenance costs are substantially lower for on-site systems than they are for central sewer systems;
- most important, the problem of water pollution becomes solvable instead of merely transferable.

Second, in cities and towns that are already sewered, implement a back-off-the-sewer program. That is, begin the process of intercepting and recovering resources — the constituents of so-called "waste" — as close to the source as possible. This does not mean closing existing central treatment facilities now; rather, it means implementing a policy of mandates to fund the use of existing technologies that can accomplish separation, recovery, and recycling at source. The aim is gradually to reduce the range and quantity of random materials entering the sewage stream, in order gradually to decrease the burden on central treatment facilities and, thereby, the volume of sludge produced. This back-off-the-sewers program includes the following:

- Do not extend sewer lines. Instead, funds now allocated for the extension of sewer lines should be saved for implementation of systematic source reduction, source separation, and resource recovery technologies.
- Upgrade the level of treatment in those plants where immediate protection of the priority recipient body of water is deemed worth the environmental damage to be incurred by the increased production of toxic sludge.
- Implement new programs of industrial point-source separation, and enforce those that exist. Because adequate data concerning industrial processes are available, it is comparatively easy to apply

specific source separation techniques to industrial wastes. It is also relatively easy for regulatory agencies to monitor and control industrial discharges.

- Beginning at the peripheries of sewered communities whose central treatment facilities are already overloaded, install composting equipment designed to convert to humus, on-site, all human excreta. This would intercept most organic and nutrient "waste" materials at their source, thus avoiding the problems characteristic of all efforts to remove them afterwards.

8.2 On-site Separation and Resource Recovery Technologies

Many technologies exist — and have been in use long enough to be well understood — which represent definite improvements over either septic systems or pit latrines from the point of view of sustainability. The most advanced in this respect is the combination of composting toilet and separated greywater treatment. Besides making sewer- avoidance possible, this approach makes it possible for all the resources involved — urine, feces, food scraps, washwater, and all the soaps and other "pollutants" in washwater — to remain in the nutrient cycles. The excreta is stabilized before removal from the composting unit and then recycled back, odorless and safe, to agriculture. The washwater is used for irrigation of trees, shrubs, and gardens around the dwelling, in which process it will be cleaned by topsoil and then replenish groundwater. In this nutrient-cycling configuration, today's damaging path of sewage creation, central collection and treatment and the resultant production of sludge, can be avoided altogether. Such genuinely sustainable technologies should be systematically supported by education and training programs, as well as by development money for mass installation, both in remediation and in new construction.

8.3 Getting the Price of Water Right

Charging the true value will necessarily tend to make the more sustainable technologies more attractive to governments and to

industries which now misuse water simply because it is so cheap. The importance of such a policy shift is self-evident.

9. Summary

Central sewage can never be made sustainable. The random mixing of unknown materials is inherently unsustainable. Spending any resources — money, time, energy, materials — on the extension of central treatment, either on the sewer lines and hook-ups or higher levels of treatment, is a waste of those resources.

From the point of view of environmental sustainability, any on-site sanitation system is better than central collection and treatment. This is true even of traditional and conventional on-site systems such as pit latrines and septic systems which can — and do — pollute. But it is precisely because they are on-site that their remediation and upgrade through replacement with non-polluting, resource-recovery technologies is feasible. And given that such remediation is technically possible to do now without lowering the quality of life, there is no legitimate reason why this course should not be systematically pursued. The technologies exist; the political will to make it happen must be mobilized.

A Historical Perspective

The history of the disposal of human excreta is as old as human civilization. As a field of study, its history is short. In 1854, Dr. John Snow removed the handle from the water pump at the corner of Cambridge and Broad streets in London, thereby containing a cholera epidemic in the neighborhood, but doing little to stem the introduction of the bacteria into the Thames River. Over one hundred years later, sanitation practitioners continue to pay close attention to pump handles and less to pollution prevention.

From privies to sewers and advanced wastewater treatment, we have exchanged one kind of public health and environmental problem for another. Some disease cycles have closed while others have opened. Industrial discharges into public sewers, water pollution from nutrient loading and chemical contamination, and freshwater scarcity are global problems all associated with "advances" in sanitation. Meanwhile, millions of adults and children suffer from diseases that could be prevented with on-site containment and treatment of excreta.

The late 20th century rush to sewer has created a widening gap in access to adequate sanitation. The lion's share of investment in environmental sanitation goes to sewerage in urban areas, subsidizing services for the middle class and rich. United Nations statistics show that only 18 per cent of rural residents in developing countries have access to sanitation, compared with 63 per cent in cities. Nearly 3 billion people do not have access to any sanitary excreta disposal, a billion more than the entire global population when John Snow made the connection between cholera and the water coming out of a standpipe in London.

Epidemiologists studying historical records can point to the impact of sanitation on people's health. Life expectancy increased as access to clean water and sanitation increased. Sewers played their part, moving pathogens from more to less populated areas. Diseases like typhoid and cholera saw dramatic reductions in urban populations with access to sewerage. But we are only beginning to understand the long-term health

and environmental costs of sewers. And the world is a much more crowded place than it was when the first sewers were built.

Abby Rockefeller, the author of the second essay in this book, "Civilization and Sludge: Notes on the History of the Management of Human Excreta," looks at the historical record and explains how unsustainable sanitation technologies were institutionalized. She notes that "the patterns of settled community behavior early split into two courses: one that unambiguously assumed there to be in human excreta a fertilizer value to agriculture, and one that did not regard it as having such a value, or that was at least ambivalent about its value." This schism and what it has meant for human health and the environment help explain the attitudes and practices that have deprived half the globe of sanitary excreta disposal, and given the other half unsustainable sanitation systems.

1. Civilization and Sludge: Notes on the History of the Management of Human Excreta

Abby A. Rockefeller

Summary

Disposal of human excreta and industrial wastes by means of the water-carriage system of sewerage has been the preferred method of management of these wastes for more than a century in all industrialized nations of the world. The pollution of water bodies caused by this practice led to treatment of the centrally collected sewage. Treatment of sewage led, in turn, to the production of sludge. Sludge consists not only of human excreta and industrial wastes, but of a myriad of nonpoint source wastes as well. Although sewage sludge was officially treated as a hazardous material by the environmental protection agencies of the sewered nations of the world, these same agencies nonetheless allowed it to be disposed of by dumping into the ocean and major inland bodies of water, by land-filling, and by incineration. Environmental damage to ocean ecosystems, air, and groundwaters caused by these practices aroused opposition from environmental groups. Between the late 1970s and early 1990s, a policy shift by the environmental protection agencies changed the classification of sludge from a hazardous material to fertilizer, and, through banning ocean dumping and curtailing land filling and incineration, mandated, instead, land application of sewage sludge. The hazards associated with the decision to dispose of sludge by putting it on land is now the subject of increasing controversy among policymakers, scientists, and citizens' groups.

People have been “civilized” — have been settled as opposed to nomadic or hunting-and-gathering — for a mere ten thousand years. And most of us *Homo sapiens sapiens* remained “uncivilized,” in the

narrowly meant sense of living without the advantages or constraints of a settled abode, for probably at least the first half of those ten thousand years.

Before people became “citizens” living in “cities,” these smartest alecks of the animal world deposited their excreta — their urine and feces — on the ground, here and there, widely dispersed, in the manner of all other land creatures. Of course, some groups, such as cats, bury their feces and urine in shallow holes. But the effect of surface deposit or shallow burial is the same: ready access by the decomposer creatures in the soil to the nutrients and stored energy in the excreta; and ready cycling through life of the elements necessary to it, attended by an incremental enrichment and diversification of the forms of life.

This process involved keeping the nutrients characteristic of excreta in the cycle of soil-to-bacteria-to-plants-to-animals-to-soil. The soil and its communities of life long ago grabbed hold, so to speak, of this major source of nutrients. Keeping these nutrients, especially the major, or “macro,” ones such as nitrogen and phosphorus, locked up in the cycles of the land, besides making the land-based life cycles nutrient-rich, kept the nutrients out of the waters of our planet. The lakes, rivers, streams, ponds, oceans, and aquifers were consequently relatively nutrient-poor — what people call “pure.” Aquatic life forms evolved in precise relation to the purity of waters, so that the characteristic of macro-nutrient scarcity has become, gradually but absolutely, crucial to the health of the species and the ecosystems of the aquatic environment.

When we speak of “healthy” eco-systems, we mean stable eco-systems; that is, both tending toward diversity and not subject to cataclysmic drops in diversity. Such conditions, also called balanced, create ever more intricate relationships, which increasingly locate the inorganic elements necessary to life in cycles that make those inorganic elements increasingly available to life. The more extensive these relationships, the more consistently available the nutrient elements will be to the life forms within those relationships. Expanding diversity of life forms is, relatively speaking, a low entropy enterprise. The more diverse the forms of life, the more matter and energy are kept available for use, or

“work,” and the less they are lost to use or work through either irretrievable dissipation or unresolvable mixing.

So pure water means more than a simple chemical state; it also means a dynamic balance between the nonliving macro-nutrient-scarce matter and the living organisms in water; a balance whereby the relationships of life forms to one another, developed over the course of perhaps a couple of billions of years, are, though always changing, nevertheless (excepting cataclysmic events) always stable, expanding in diversity, and healthy.

It is not that life will disappear in waters suddenly enriched by an infusion of macronutrients. (Nitrogen and phosphorus, both called macronutrients because most plants need large quantities in order to grow, are also sometimes called “limiting factors” since the growth of plants — including algae — is limited in direct proportion to their scarcity.) But the effect of sudden infusions of any of the macronutrients will be to reduce the diversity of life in any body of pure water. We call waters polluted that look like pea soup, so full are they with life — cyanobacteria and green algae — because we understand that even a very great abundance of a single form of life in, say, a lake doesn’t mean that all’s well with the life system in the waters of that lake.

And, indeed, all is not well — much is, in fact, dreadfully wrong — with most of the waters on Earth. What happened to make this so? In brief, there was a sudden infusion (sudden compared to the slow pace of evolution) of nutrients into the Earth’s waters — an infusion, that is, in the form of water-borne human excreta. What follows considers how water came to be used to transport human excreta, how bodies of water came to be used as the recipient dumps for water-borne excreta, and what environmental effects have been associated with the chain of behavioral and technological developments resulting from these practices.

Much of the history of human behavior is before our eyes in living societies today, the history of our excretory practices not excepted. It is likely that all practices ever associated with the disposition of excreta

still continue in some societies. The patterns of settled community behavior early split into two courses: one that unambiguously assumed there to be in human excreta a fertilizer value to agriculture, and one that did not regard it as having such a value or that was at least ambivalent about its value.

It was, to be sure, agriculture that “caused” civilization: in its simplest and in its most elaborate forms, civilization altogether depends on agriculture. This dependence, however, has not inspired all agricultural societies with reverence for the economy of the cycles on which agriculture is dependent. Especially uneven has been awareness of the economy of giving back to the soil in the form of excreta what has been taken out in the form of food. The cultures that did consistently employ their own manure in agriculture were primarily Asian. Much has been written about the longevity of these civilizations and the significance of the persistent use of human manure for that longevity (King 1927).

Those settled cultures that do not — and did not — connect human manure with sustainable agricultural productivity, followed, and still follow, a fairly standard pattern of “development” of their “sanitation” habits. Urinating and defecating on the ground’s surface in the manner of pre-civilized days, but in the immediate vicinity of their dwellings, is the first phase. This soon becomes unviable — that is, too unpleasant — due to the increasing density of the settlers: this leads to the creation of the community pit. When privacy of excretory functions comes to be deemed important, then comes the pit privy, the privacy structure on top of the hole in the ground.

This “outhouse” is placed at a distance from the dwelling, on account of the smell. The odor caused by concentrating excreta in one spot in the manner of the pit latrine — an olfactory offense that causes many to choose the bushes — is legendary for its unpleasantness. But stink aside, and contrary to what some people think, the pit latrine — with or without the privacy structure — is not, and never was, environmentally viable. The pit toilet causes two related troubles — waste and pollution: waste through loss of the unretrieved nutrients in the excreta, and pollution of the ground waters by those same wasted nutrients. To be

sure, the pit privy is not, from an environmental point of view, anywhere near as damaging as the flush toilet. But the kind of damage it caused — and still causes — is of a piece with the kind caused by the string of technologies, flush toilet included, that evolved in response to the pit privy's inadequacies.

European societies were for centuries ambivalent in their attitude toward their excreta. Was it a fertilizer source for agriculture or a nuisance to be “got rid of”? Before the advent of piped-in water, human excreta was deposited in cesspools (lined pits with some drainage of liquids) or vault privies (tight tanks from which there is no drainage) in the backyards of European towns. The “night soil”— human manure collected at night — was removed by “scavengers” and either taken to farms or dumped into streams or rivers, or in “dumps” on the land. In Europe, there was, in other words, no consistent perception of the agricultural value of these materials — not as in Asian cultures, where the husbanding of human excreta was (until very recently) unexceptional and routinized.

Five hundred years before Christ, Rome already had in place a system both for bringing in pure water through its famous aqueducts and for the removal via sewers of fouled water that included water-borne excreta from public toilets and from water closets in the homes of the rich (Pliny the Elder 1991; Mumford 1961). But until the middle of the 19th century, most of Europe prohibited the use of sewers for the disposal of human excreta. Sewers consisting of open gutters or sometimes covered trenches in the center or sides of streets had long been in use in European cities, but only for the drainage of rain run-off and for city filth. However, household transgressors used the sewers to dump their kitchen slop water, and — to save on the cost of paying scavengers — the contents of chamber pots and overflowing cesspools. And when going all the way to the farm was an inconvenience or an extra expense for professional cesspool scavengers, they too took surreptitious advantage of the sewers to dump the accumulation from their nightly labors. The putrefying matter in these stagnant ditches moved along only when it rained enough (hence the name “storm” sewers), and digging them out with shovels was the job of the “sewermen” (Reid 1991).

The “water closet” (so-called to distinguish it from the “earth closet,” an early species of compost toilet much favored by 19th century environmentalists) afforded the enormous convenience of simultaneously putting the toilet in the house while getting the excreta out of the house. The “flush” toilet had been known to the privileged at the height of the Roman era and since the 18th century in northern parts of Europe. But this pivotal technology, still a symbol of civilization, came to widespread use only after piped-in water had been made available to the major cities of Europe and the United States. The first waterworks in the United States were installed in Philadelphia in 1802. By 1860 there were 136 systems in the U.S., and by 1880 the number was up to 598 (Tarr and Dupuy 1988). The convenience of a constant water supply stimulated the adoption of residential water fixtures — baths and kitchen sinks as well as flush toilets — dramatically increasing the per capita use of water on average from three to five gallons per person per day to 30 and even 100 gallons per person per day.

Of course, once water was in great quantities piped into homes, it had to be piped out again, and the first “logical” place to pipe it, including the flush water from water closets, was backyard cesspools. These cesspools, which hitherto had received the contents of chamber pots — urine and feces only — now regularly overflowed with fecally polluted water, and a new level of horrendous odors and the spread of water-borne diseases were the immediate results.

Thus the system of cesspools and vault privies, which had been to some extent effective in avoiding pollution of waterways through their periodic clean-out by scavengers and the at least partial returning of human manure to farms, was overwhelmed by the pressure created by the new availability of running water. The next “natural” step in the solve-one-problem-at-a-time approach was to connect the cesspools to the sewers, thereby moving the sewage from overflowing cesspools into the open sewers of city streets. The result: epidemics of cholera. In 1832, 20,000 people died of cholera in Paris alone (Reid 1991). Wherever and whenever this combination of piped-in water, flush

toilets, and open sewers has appeared in the world, epidemics of cholera have followed.

By the middle of the 19th century, the diseases spawned by the convenience of running water and the flush toilet gave rise to a demand for the construction of sewers that would carry the sewage not only out of and away from the home, but away from the city as well. This demand entailed the evolution of the ditch-type storm sewer into the closed-pipe water-carriage system of sewerage. The wastewater itself was in this system the medium of transportation, so a large and regular supply of water was a built-in requirement to keep the wastes moving in the pipes (Tarr and Dupuy 1988). (Today, efforts to conserve water by promoting the use of low-flush toilets — 1.6 gallons vs. five to seven gallons — have led to plugging of sewers engineered for a minimum hydraulic flow of five gallons per flush. To deal with this problem, owners of these “water-conserving” toilets have been instructed to flush two or three times per use.)

The water-carriage system of sewerage introduced a new set of problems and, about these problems, a new set of debates among sanitary engineers in Europe and the United States. The engineers were divided again between those who believed in the value of human excreta to agriculture and those who did not. The believers argued in favor of “sewage farming,” the practice of irrigating neighboring farms with municipal sewage. The second group, arguing that “running water purifies itself” (the more current slogan among sanitary engineers: “the solution to pollution is dilution”), argued for piping sewage into lakes, rivers, and oceans. In the United States, the engineers who argued for direct disposal into water had, by the turn of the 19th century, won this debate. By 1909, untold miles of rivers had been turned functionally into open sewers, and 25,000 miles of sewer pipes had been laid to take the sewage to those rivers (Tarr and Dupuy 1988).

In cities with water-carriage sewers, cholera epidemics abated. However, in cities downstream from those dumping raw sewage into the river, death rates from typhoid soared. This led to the next debate: whether to treat the sewage before dumping it into the recipient bodies

of water or whether to filter the drinking water downstream. Health authorities argued that sewage should be treated before disposal into any bodies of water, but the sanitary engineers preferred filtration by the next town down the river. The engineers prevailed, and indeed, in those cities with filtered water, deaths from typhoid dropped dramatically (Tarr and Dupuy 1988).

The practice of “purifying” water polluted with sewage from upstream in order to make drinking water safe downstream, rather than treating sewage where it is produced, persisted until the middle of the 20th century. By then, the rate of industrial development had been enormous, and every industry wanted cheap disposal of its wastes. And since the public was paying, dumping industrial wastes was cheap as could be. Industries’ demand for more sewerage to serve their own disposal needs stimulated the industrialized nations of the world to allocate vast sums of money for massive sewer construction programs.

To the recipient waters’ burden of human excrement, then, was added a new and ever increasing flow of industrial waste, much of it toxic. And wherever on the globe there were sewers, the recipient rivers, lakes, and streams were soon discovered to have become unacceptably filthy, in response to which came pressure to treat the sewage before it entered those waters. And so began the “treatment” phase of the get-rid-of-it approach to dealing with wastewater now consisting of human excrement mingled with industrial wastes transported by water.

The first step in the effort to clean up the sewage before sending the effluent into the river is termed “primary treatment.” From the point of view of improving water quality, it is a crude method, consisting of little more than settling and screening the sewage to remove the largest and most aesthetically offensive objects: all nutrients and chemicals not tied up in dead cats and intact feces remain in the water.

The next, the “secondary” stage of treatment, includes some biological stabilization through forced aeration of the sewage, and chemical flocculation and precipitation of some of the phosphates deriving from laundry detergents. In spite of the great energy and financial cost of this

form of treatment, the effluent reaching the recipient bodies of water continues to be rich in nitrates and phosphates. (These nutrients, as noted above, are called limiting factors. When they are present in water, they cause an explosive growth of algae, which in turn causes lakes to die of eutrophication as the decaying algae rob the water of its oxygen.) Industrial pollutants, such as toxic chemicals and heavy metals, are not addressed by this level of treatment.

So engineering ingenuity developed another, yet more complex, yet more energy intensive and expensive process, called “tertiary” or “advanced wastewater treatment.” Because of its enormous cost, it has been difficult to get American taxpayers to fund this level to any great extent. But even where funded, treatment remains incomplete: some nitrates, some heavy metals, and many toxic chemicals evade tertiary treatment and remain in the water.

Central collection and treatment of sewage cannot be said to have succeeded in solving the underlying problem of water pollution caused by using water to transport wastes. The problem is deeper and systemic. The trouble with the treatment approach to managing the pollution caused by water carriage of excreta and the by-products of industry lies only partly in the inadequacy of even the most advanced processes. Though the trouble may seem to have been ameliorated because this bay or that river is less polluted than it was without wastewater treatment, the pollutants that were in the water have simply been reorganized and concentrated in a new form: sludge.

Sludge is the dewatered, sticky black “cake” consisting of every waste material capable of being sent down the drains of homes and industries and into the sewers, and which the treatment process is able to get back out again. If sewage can be said perfectly to exemplify a high entropy process of matter lost through irretrievable dissipation, sludge is the quintessential example of disparate matter lost to use through unresolvable conglomeration.

In the *United States Federal Register* (Vol. 55, No. 218/November 9, 1990), the United States Environmental Protection Agency (EPA) says of sludge:

The chemical composition and biological constituents of the sludge depend upon the composition of the wastewater entering the treatment facilities and the subsequent treatment processes. Typically, these constituents may include volatiles, organic solids, nutrients, disease-causing pathogenic organisms (e.g., bacteria, viruses, etc.), heavy metals and inorganic ions, and toxic organic chemicals from industrial wastes, household chemicals, and pesticides.

This short list of what sludge “may include” is but a sampling from the enormous list of constituents that can actually be present in it. For instance, of the 100,000 or so organic and inorganic chemicals produced and used in industrialized nations, a huge number end up in the sewers. One thousand new chemicals are produced every year and are added to the cocktail of synthetic substances affecting life processes. Those pollutants that are put in the sewers — and removed from the wastewater by the treatment process — will end up in the sludge. There are the heavy metals which, though they are micro-nutrients crucially needed in tiny amounts for growth of life, are toxic to life when they exceed the boundaries firmly established over the eons during which the cells of life evolved. There are organochlorine estrogen mimickers, the best known of which are DDT, chlordane, alpha-hexachlorocyclohexane, 2,4,D, PCBs, and dioxin. There are halogenated aliphatic (chain) hydrocarbons, aromatic (ring) hydrocarbons, chloro- and nitro-aromatic hydrocarbons, phthalates, halogenated ethers, and phenols. There are the ubiquitous APEs or alkylphenol ethoxylates, the surfactants in the detergents of home and industry — the *biodegradable* detergents — which when they break down in the treatment plant, become estrogen mimickers and lethal to fish. There is radioactive matter from hospitals. All of these are destructive to life processes (Reutergårdh 1966).

Attitudes toward sludge — this heterogeneous product of wastewater treatment processes — and toward the disposition of it have a

convoluted history of their own. Clearly, sludge contains constituents that are hazardous to life. If we persist in producing sludge, something must be done with it. What to do with it is the subject of intense debate. To understand this debate, one must know something of the interplay between the following forces: the environmental movement that began in the early 1970s; the organic food movement that began decades earlier; the traditional sanitary engineering/regulatory posture; and the exigencies of the prevailing economic/industrial arrangement. The character of the debate taking place in the United States is illustrative of the way these forces interact in all the sewerred, and about-to-be-sewerred, parts of the world.

To begin, it may be clarifying to focus this history on the question of why decentralized solutions to water pollution were not developed and promoted in preference to sewerred, since, environmental considerations aside for the moment, they would have saved taxpayers immense amounts of money. The answer is found in part in the engineering/regulatory bias in favor of top-down, centrally controlled solutions. Health authorities are traditionally skeptical of people's ability to manage problems themselves. The regulatory and sanitary engineering community (very much one body, in general) feels that troubles are safer in its hands. Moreover, there has been a widespread conviction on the part of many environmental groups that treatment at the "end of the pipe" — the sewer pipe — is the surest way of cleaning up polluted water. The environmental movement in the United States played a large part in creating the pressure that resulted in the Clean Water Act of 1977. This Act was effectively a sewerred act. Enormous sums of money were allocated for the laying of sewer pipes and the construction of treatment plants. The Clean Water Act funded virtually no on-site, site specific, decentralized systems — either for remediation or for new construction.

But the greatest force behind the drive to sewer has been the interests of industry — first, because public sewers are the cheapest place for industries to put their wastes, and second, because it is the enormously expensive system of central collection that generates the highest profits for engineering and construction firms. For example, 80% of the total

cost of sewerage and treatment is in the laying of pipes, and engineering and construction firms get a flat 20% of the total project cost. Fixing the 5-10% of septic systems that are failing (i.e., backing up or “puddling,” to which all septic systems contribute, and which is almost never cited as a cause of failure) would never generate the profits associated with sewerage 100% of these communities’ central collection and treatment works.

This powerful coincidence of seemingly disparate interests — regulatory, environmental, and industrial — has overwhelmed any popular opposition to the tax burden required to fund this massive public project, which in cost is second only to that of the U.S. highway construction program. When environmentalists are for it, and the governments are for it, corporate interests can just lay low, for who but a philistine would object to tax increases for so good a cause? Thus, town after town, each, as noted above, with typically 5-10% of on-site wastewater systems (mostly old cesspools and “modern” septic tank/leach fields) deemed to be failing, has been herded down the sewer path, and so has come to have 100% of its sewage centrally collected and treated. Since it is treatment of sewage that creates sludge — and since the more extensive the treatment, the more and the worse the sludge — the issue of how to dispose of it has become for municipalities a major and growing problem.

What has been done with sludge? In some places it has been dumped in “sanitary” landfills, where it has caused serious groundwater pollution. In other places it has been incinerated, causing serious air pollution. And, remarkable as it may seem (given the stated objective of removing pollutants from the water), during the first phase of the sewage treatment era, cities built on ocean shores saw fit to dump the sludge into the ocean — that is, back into the water. As early as 1924, New York City, whose new treatment plant was a striking case in point, began dumping its sludge 12 miles outside New York Harbor. Sixty years later, the U.S. EPA determined that the coastal waters had been unacceptably damaged and ordered that the sludge be barged farther out — to a site 106 miles offshore. Although this strategy seems to suggest a failure of imagination, it remained an acceptable solution in the eyes

of the federal authorities until the 1980s, when hypodermic needles and other medical debris from hospitals started washing up on the beaches. (These needles actually came from “solid waste,” or trash, which was also routinely dumped into the ocean.) The barren moonscapes on the ocean floor created by the intense concentrations of heavy metals and other toxins present in the sludge had been of little concern to the public (who couldn’t see it and for the most part didn’t know about it). But the AIDS epidemic and its attendant focus on hypodermic needles caused a public and media commotion sufficient to cause Congress in 1988 to ban altogether ocean dumping of sludge.

This was a triumph for many environmental groups who had fought ocean dumping because of its toxic effects on marine ecosystems. But the ban on ocean dumping only moved the sludge problem to other grounds: *now* what to do with it? And, although not a conflict known to many — not even to many environmentalists — there was a disagreement within and between the groups in the environmental movement over what should be done with the sludge. It seemed that the old debate had reappeared, only this time about sludge: is it a nuisance — or worse, a hazard — that must be “disposed of”; or is it, like the old “night soil,” a valuable fertilizer?

Some major environmental organizations — including the Environmental Defense Fund (EDF) and the National Resources Defense Council (NRDC) — struck a deal with the EPA, which agreed to shut down ocean dumping if these environmental organizations would join in promoting land application as the long-term solution to the disposition of sludge. Both EDF and NRDC were among the signers of the “consent decree,” the legal document mandating land application in place of ocean dumping. To many in these organizations, this must have seemed a very good arrangement: in one fell swoop it ended a poisonous process (ocean dumping) and, it seemed, began a very good one. Wasn’t this a promise to “recycle”? Wasn’t it “sewage farming” at last?

The organic farming and natural food movement developed in response to agriculture’s post-World War II turn to chemical fertilizers and synthetic pesticides. By the 1950s and ‘60s, the organic gardeners and

farmers movement had attracted a diverse, passionate, and international following, soon to join the more encompassing environmental movement of the 1970s. Fundamental to the organic movement's philosophy is the belief that human health depends on food grown on soil alive with humus, the partly decomposed residue of organic matter, rather than on food fed "intravenously" with soluble synthetic chemical fertilizers, as is the practice in agribusiness. Hence, for the organic food and agriculture movement, compost, the managed creation of humus, is of the essence of the organic method. Crucial to this orientation, also, has been the belief that, since all life is related, the pesticides, herbicides, and fungicides routinely employed in chemical agribusiness will damage human health at least as much as they will damage the smaller and rapidly multiplying creatures they were designed to destroy. This is the fundamental logic of the organic movement's abhorrence of the use of sewage sludge in agriculture.

The organic food and agriculture movement gained strength in spite of the silent but monumental opposing interests of the agri-industry, whose financial health has depended on petrochemical-based fertilizers and also, given vertical integration of the chemical and agriculture industries, on petrochemical-based pesticides. The organic food and agriculture movement gained strength also in spite of the ruling view of the EPA, an institution to a large extent composed of engineers with little respect for ideas associated with anything "organic." Indeed, the U.S. Department of Agriculture and the EPA regarded the practice of composting, the organic farmers' means of achieving soil health and fertility, as being unscientific — until the late 1980s, when, soon after the signing of the consent decree stopping ocean dumping of sludge, "land application" of sewage sludge came into its own.

In 1992, the ocean dumping ban went into effect, and then, with the full fanfare and pomp of a formidable public relations campaign, sewage sludge was rechristened "biosolids" and called "beneficial" to boot. Thus the EPA's classification of sludge as a hazardous material was evaporated, and then reconstituted with the trappings of the only recently despised word "compost": sludge would be composted; the

word “compost” would achieve official dignity. And environmental groups such as EDF and NRDC blessed this conversion.

At the same time, industry and the big environmental organizations were forging a new kind of relationship. These groups believed they could modify the behavior of industry in favor of the environment by sitting, in a spirit of negotiation, at the same table. Industry on its part began to fund the big environmental organizations. EDF and NRDC both received funding from the waste handling industries, and subsequently were notably silent when questions were raised about the toxic constituents of sludge and the likely dangers of its application to the land. Within the organic movement, *Compost Science*, a spin-off of Rodale's very popular *Organic Gardening and Farming* magazine, became the prime publicist of land application of sludge, not only through its articles, but also through its copious advertisements for sludge hauling and sludge spreading equipment.

This sanction by respectable environmental organizations was key to getting public and regulatory acceptance for what would be, for the waste industry, the most profitable sludge disposal method among all the alternatives. Land filling has become expensive because of ever increasing tipping fees. Incineration is expensive because of unabated environmental opposition. Land application, on the other hand, is cheap. Taxpayers' money pays waste haulers to take the sludge away and then dump it — for free! — on farmland. And beyond free dumping, through high-powered public relations expropriation of the words “natural,” “organic,” “compost,” this same sludge, neatly pelletized and bagged, could be sold retail to gardeners. And, as long as there were environmentalists who condoned it, even would-be organic gardeners would buy it.

For every municipality with a sewer system and some kind of sewage treatment, the growing mounds of sludge are becoming an increasingly serious problem. This problem gives municipalities a compelling interest in supporting land application: every town and city needs a way — a cheap way, if possible — to dispose of this sludge. The public, already burdened by taxes first for sewerage and then for treatment of

sewage, will not easily take on the further cost of the “treatment” of sludge. According to the government/industry PR, land application isn't treatment: it is “beneficial reuse,” and it costs taxpayers nothing. And along with their offer of sludge as a “free fertilizer” to the farmers, waste haulers began offering as well the free spreading of lime, a bonus worth thousands of dollars that small and middle sized farmers in those parts of the country with acidic soils in need of liming would find very tempting indeed.

The claim that sewage sludge is “beneficial” is based on the presence in the sludge of nutrients deriving from human excreta. But the benefit of this content compared to the dangers of the toxic matter also in sludge is a key point in the debate about land application.

It is the view of this writer that the menace of toxic and otherwise non-life-compatible substances found in sludge so greatly outweighs the potential nutrient benefit as to make that potential benefit an irrelevance. Let me now present the reasoning on which my position is based.

Nitrogen is the main nutrient promoted to farmers as the “free fertilizer” in sludge. Those in EPA (located in the Water Division) who promote land application claim that the total nitrogen fertilizer requirement of agriculture can be met by using sewage sludge. However, while it is true that there is an amount of nitrogen in the raw sewage, deriving primarily from urine, and while it is probably true that this total amount of nitrogen, if captured, *could* meet the needs of agriculture, the forms of nitrogen in sewage are highly soluble and, once mixed with water, are not easily removed. Because of this solubility, most of the nitrogen remains in the wastewater, transferring correspondingly little to the sludge. Since the concentration of nitrogen is so relatively low, and the concentration of heavy metals (e.g., lead, cadmium, zinc, copper, mercury, chromium, and arsenic) and all other toxins certain or likely to be present, is, relative to ambient levels in soils, so high, it follows that massive quantities of sludge must be spread on farmland to attain the levels of nitrogen needed by the crops. This means heavy metals will accumulate in the soil. Or they will move. Where? Into the groundwater, into bacteria, into plants, into the chain of life.

The offer of free lime, besides serving as an inducement to farmers to accept sludge on their land, serves another purpose. The regulations governing land application of sludge require the maintenance of a pH above 6.5 in soils on which sludge is spread. This 6.5 pH is needed in order to bind up the heavy metals — precisely to prevent them from moving — either up, causing “bio-accumulation” in life chains, or down, causing pollution of groundwater. There is an active debate between soil scientists and advocates of land application about this effort to “bind up” the heavy metals. This debate involves two questions: whether or not (from a strictly chemical point of view) liming works on all the metals, and whether or not it matters if it works, since the monitoring and enforcement of pH levels on farms is a virtual impossibility.

There are many problems surrounded by intense controversy over the issue of land application of sludge. Its noxious odor is the first to be complained of — though the least threatening to life. Disease from viability and re-growth of human pathogens in raw sludge, and other diseases caused by the sludge composting processes (the growth of certain fungi that can damage the lungs), are of major concern to many.

But serious as these concerns are and serious as is the danger of toxic levels of heavy metals building up in the soil, sludge has another yet more threatening characteristic. *Combinations* of some chemicals can cause levels of disruption in life processes many times more dangerous than the effects of these chemicals alone. For example, recent research has demonstrated dramatic increases in the estrogenic effects of common pesticides when they act in combination. Whereas the endocrine disrupting effect is 1:1 in the case of the doubling of one single compound, where two or more compounds are combined, their destructive effects are not just doubled but, rather, in some cases multiplied and magnified to the order of 600 or even 1600 times. Sludge provides the perfect conditions for combinations of thousands of chemicals, and these could cause a cataclysmic devastation of life (Colborn et al. 1993; Arnold et al. 1996).

What is to be done with sludge, then? This question has two parts. The first is immediate: is there a safe way to deal with the sludge that the world is now producing? The second is a policy question: should we continue to commit resources to a system of sewerage and treatment of sewage, which creates so unresolvable a problem as is embodied in sludge?

As to the immediate question. The sludge produced by existing treatment plants should be treated as the hazardous waste that it is: it should be isolated in secure storage, as nuclear waste is. There are emerging technologies such as gasification, which, through high-heat oxidation, can, at least, reduce the sludge to an isolatable mineral block or ash. However, secure storage, no matter how reduced the mass, is not a viable long term solution, consigning as it does so much matter — valuable had it never been mixed — to the most absolute waste heap. But secure storage has the advantage of making possible in the short term the minimizing of contact of sludge with life. Land-application maximizes the contact of sludge with life, and maximizes thereby the danger of sludge to life.

The answer to the second question — the policy question — is prevention. Prevention, rather than inevitably futile attempts at “cure,” is the form that any adequate change must take. Prevention means not creating sludge in the first place. Communities that are not already sewered should practice sewer avoidance. Sewering and central treatment are, when all costs are counted, by far the most expensive technologies; they radically degrade the environment rather than protect it, and produce sludge in overwhelming quantities. Communities need to take the political initiative to insist that substandard or failing on-site systems (e.g., pit latrines, cesspools, septic tank/leach fields) be remediated by on-site technologies that solve, rather than merely move, the problem. Many options already exist for on-site remediation of failing, polluting septic systems.

Let it be repeated: the key to preventing the trouble caused by the sewer’s mess of mixed matter is separation at the source, where each material, appropriately treated, can be returned to its place in the cycles

of life and industry. Technologies exist now that can solve — on-site — this “problem of human waste.” It is a matter of the political choice of policies that could take us in a direction that is technically feasible, financially preferable, and environmentally sustainable. Such a change can be accomplished on any scale.

Conclusion

No civilization in the world today deals well with human excreta. At all levels of technical sophistication — pit latrine, flush toilet, septic tank/leach field, or, most insidiously and destructively, the system of central sewage collection and treatment which creates an unpredictably toxic, and therefore non-recyclable, sludge — the most serious damage possible is done to water, soil, and human health and the environment at large. The only way we can protect simultaneously the soil, water, and human health is through technologies and management systems that keep human excreta separate from the rest of our “wastes” and return it to agriculture, from which for the past 10,000 years, it has come.

The sheer number of dangers associated with applying sludge as fertilizer is so great, so various, and so serious that it would be the life work of thousands of professionals to divide up and respond to the categories of problems that arise from this practice.

Do we know what significance to assign to all the “merely anecdotal” reports of cows sickening and dying after eating hay and silage grown on sludge; of people who, living next to agricultural lands to which sludge has been applied, develop strange illnesses? Yes! The real significance lies precisely in sludge’s fundamental unpredictability. What goes down the drains is unpredictable. What goes into the sewer — from hour to hour, from week to week, from month to month — is unpredictable. What is extracted from the wastewater can neither be predicted nor monitored to an extent even remotely adequate. And no system of regulations can be either designed or enforced in such a way as to protect life chains from the potential of devastation by the unpredictable constituents of sludge, unpredictable in their incidence and in their consequences.

Collecting our “wastes” in sewage, then “treating” them so as to disentangle them again, then distributing the residue, the sludge, on agricultural land, can be made to look like “recycling,” for some of the sludge did come from the processes of food growth and food use. But a great deal of it did not come from such processes. When those materials foreign to life are insinuated into it through the food chain, the consequences for life can be terrible. Because we cannot find either a certain way either to keep all the toxics out of the sewers or a way to get all the toxics out of the sludge, we must say, I think, that the consequences of dumping sludge on agricultural land *will* be terrible.

To accept the view that the benefits of applying sewage sludge to agriculture will outweigh the harm is either sentimental evasion or shortsighted greed. The unpredictability of sewage sludge is its essential character. And when this unpredictability risks damage to all life, on the order that industrial society's toxic chemicals certainly involve, gambling on the dangerous route is absurd.

Current Practices

Akhtar Hameed Khan, Director of the Orangi Pilot Project in Karachi, Pakistan, described the grim facts of the current status of global sanitation in UNICEF's 1997 *Progress of Nations* study: "On the brink of the 21st century, half the world's people are enduring a medieval level of sanitation. Almost 3 billion individuals do not have access to a decent toilet, and many of them are forced to defecate on the bare ground or queue up to pay for the use of a filthy latrine. This unconscionable degradation continues despite a fundamental truth: Access to safe water and adequate sanitation is the foundation of development. For when you have a medieval level of sanitation, you have a medieval level of disease, and no country can advance without a healthy population."

According to the World Health Organization, the 1990s saw a decrease in the number of people with access to sanitary excreta disposal. Interventions are not keeping up with population growth. World population has increased fourfold since sanitation entered the lexicon of engineers and public health advocates in the mid-1800s. The United Nations projects a tenfold global population increase by 2050. Access goes down as population goes up. The same relationship holds between access and international debt. As debt soars in poor countries, expenditures on sanitation plummet. One example is Kenya, where less than 50% of the population has access to sanitation. While its international debt climbed in the 1980s, its biggest city, Nairobi, saw capital expenditures for water and sewers drop by a factor of ten.

Because sanitation with environmental health in mind is a low priority with international development organizations and governments, industry and financial institutions have greatly influenced the direction the sector has taken, favoring centralized, capital intensive services and technologies.

Some estimates put the price tag on providing universal sanitation at \$68 billion. This money might provide coverage, but without a radical

rethinking of how it is spent, one set of problems will only be exchanged for another. Unless the political and community will to adopt source separation, recovery, and reuse as fundamental goals for the sanitary disposition of human excreta is realized, pollution will remain the legacy of modern sanitation systems.

Nutrient-rich water, nutrient-poor soil, and sewage sludge are the products of current sanitation technologies. Sustainable sanitation practices would put the nutrients where they belong, out of water and into agriculture.

This section takes a look at a sustainable practice and an unsustainable practice: source separation vs. treatment at the end of the pipe. Gary Gardner tells us what we can do better. Laura Orlando describes a course of action we should avoid.

2. Recycling Organic Waste: From Urban Pollutant to Farm Resource

Gary Gardner

Introduction

In 1876, a German chemist studying the agricultural history of North Africa became increasingly troubled over the fate of that region and its implications for his day. In the first century AD, North Africa's fertile fields were supplying two thirds of the grain consumed in Rome. But the nutrients and organic matter in that food were not returned to the farms where they originated; instead, they were flushed into the Mediterranean. By the middle of the third century, the one-way flow of nutrients out of North Africa's grainland soils, along with declining levels of organic matter, had contributed to the region's tumble into environmental and economic decline.¹

The chemist, Justus von Liebig, worried that Europe's rapidly expanding cities also depended too heavily on one-way nutrient flows, with consequences that would eventually undermine both urban and agricultural areas. To solve the problem, he invented chemical fertilizer, essentially a mixture of condensed and easily transportable nutrients that made it possible to escape dependence on recycling organic matter. The new fertilizer revived the fertility of nutrient-depleted farmland. And because a ton of this plant food could pack as many nutrients as dozens of tons of organic matter, it could be shipped cheaply over great distances. Cities could now expand, and food could be imported from great distances, without concern for returning urban garbage and sewage to farmlands. Thus, garbage and sewage became waste products to be discarded, rather than soil builders to be reused.

Today, nearly 3 billion of us — half of the human family — live in cities, more dependent than ever on long, one-way flows of nutrients and

organic matter. But reliance on linear flows instead of the traditional organic "loop" comes at a price that is paid at both ends. To start with, many regions of the globe are now overfertilized, a trend with consequences well beyond the farm. Drinking water in several European countries is contaminated with fertilizer runoff. Species diversity is reduced in some land-based ecosystems by excess applications of nitrogen. The quality of organic matter declines, and plant diseases become more prevalent, in soils dependent on manufactured fertilizer. And aquatic life in rivers, lakes, and bays suffocates as blooms of algae fatten on nitrogen and phosphorus that have leached and eroded from these soils. In short, a host of new problems arise once the circular flow of nutrients (essential for plant growth) and organic matter (essential for soil health) is disrupted and made into a linear flow.²

At the disposal end of the linear flow, meanwhile, natural sources of nutrients and organic matter in urban garbage and human excreta are increasingly difficult to eliminate safely. Landfills for solid waste are not only near capacity in many countries, they are leaking toxic chemicals into groundwater and methane into the atmosphere. Discarded garbage piles high on street corners in many developing countries, spawning rats and disease. And human waste is either dumped indiscriminately or mixed with industrial chemicals in urban sewers, which makes safe disposal much more difficult. In any case, sewage systems are expensive and water intensive — flush toilets account for 20-40 percent of residential water use in sewerred cities of developed countries — making them an inaccessible luxury for the growing number of cash-strapped and water-short cities in the developing world.³

Returning nutrients in organic matter to farm soils — "closing the organic loop" — would help alleviate all of these problems. Urban wastes such as food scraps, paper, and yard clippings can be composted and applied to soils, thereby improving soil structure, supplying nutrients, and suppressing disease. Indeed, nutrients in the garbage and yard wastes of states belonging to the Organisation for Economic Co-operation and Development (OECD) equal some 7 percent of the nutrients in fertilizer applied in those countries, and the level is much higher in many developing countries. In addition, nutrients in discarded human waste in

OECD countries equal another 8 percent of applied fertilizer. While urban organic wastes will not displace fertilizer entirely, they can help reduce excessive fertilizer use (and the pollution this causes) as they build healthier soils.⁴

Recycling organic matter would also ease the pressure on costly waste disposal facilities. Organic matter accounts for a third of inflows to landfills in industrialized countries, and as much as two-thirds in developing countries, and is largely to blame for the acidic leaching and methane problems that these facilities generate. Meanwhile, opting for a “dry” system of human waste management — through the use of composting toilets, for example — would free up clean water for more vital uses, and avoid costly infrastructure construction as well.⁵

Before extensive reuse of organic material can take place, however, certain changes in agricultural production and trade practices must occur. As organic flows extend across oceans, and as agricultural production becomes more specialized and intensified, nutrients inevitably accumulate in some areas. Centralized livestock facilities, for example, like the giant poultry- and hog-raising operations in the United States, buy feed from far away, and then have trouble disposing of all the manure they produce. Manure is one nutrient source that has commonly been recycled, for livestock and crops located on the same farm easily fed each other. But as livestock operations increase in size and become separated from agriculture, more and more of this resource is viewed as waste material.⁶

Such regression is also evident in some developing countries that mimic the nutrient management practices of industrialized nations. China, for example, used organic sources for more than 98 percent of the fertilizer applied to soils in 1949; today, because of rising labor costs, the share is less than 38 percent. On the other hand, some industrialized regions are paying greater attention to reuse of organic matter as the problems created by linear flows of nutrients mount. In the U.S., 23 states now restrict the inflow of grass clippings to landfills; this material is composted or re-used as mulch. And well over a third of U.S. and European sewage

sludge is now applied to land, though often with only minimal precautions for safe reuse.⁷

Continued progress in recycling organic material requires that it be viewed as a natural resource, not as waste matter. Such a shift in perspective will require education on many levels. Policymakers and citizens will need to learn to manage organic matter in ways that facilitate its reuse. Processors of organic matter, such as compost makers, will need to tailor their products to the diverse needs of different soils and crops. And farmers will need to understand how organic matter works in soils, and how they can avoid overuse of chemical fertilizers. Once this educational process is complete, other steps will follow naturally. Communities will close dumping sites to organic materials as people adopt environmentally supportive disposal technologies and management practices — such as garbage and sanitation systems that segregate organic matter from harmful chemicals and non-organic wastes. Together, these steps will promote circulation of more organic matter.

Recycling organic wastes and returning them to productive soils would be a large step toward sustainability for the world's cities and national economies. But the current trend in most of the world — toward greater dependence on extended, one-way nutrient flows facilitated by heavy fertilizer use — promises increased ecosystem disruption, greater waste disposal problems, and eventually a negative effect on food production itself. As policymakers grapple with the multiple problems of today's burgeoning cities, they would do well to ponder the multiple advantages that emerge from the wise reuse of organic matter. By retapping this important natural resource, decisionmakers can ease the urban burden on several fronts.

The Cost of Breaking the Loop

When the natural circular flow of organic material is broken, two challenges immediately arise: the flow must be fed at one end, and emptied at the other. What once occurred automatically in a cycling system, where feed and waste chased each other perpetually now requires conscious intervention at either end. The inflow challenge is typically met

with a steady stream of manufactured fertilizer, while disposal is handled in several ways, depending on the material's final form: sewage, garbage, or manure. These endpoint manipulations make linear flows possible. But they also create new problems. Today, the price for breaking organic loops is a diverse set of problems, from pollution and poor soil health caused by excessive dependence on fertilizer, to difficulty disposing of nutrient-laden wastes cleanly.

At the front end of the organic pipeline is a set of problems created largely by the overuse of fertilizer, the pipeline's "pump." When it was invented, fertilizer was viewed as a godsend: by separating the major nutrients from their host environments — nitrogen from the air, and phosphorus and potassium from rocks and minerals — scientists developed a potent and portable resource that eliminated the need to recycle bulky organic matter. Fertilizer also increased crop yields, and in combination with cheap transportation it allowed the development of large cities, which could grow without concern for returning organic wastes to the ever-more-distant fields on which they depended for food. Unforeseen, however, was the growing human and environmental toll that would result from excessive dependence on chemical fertilizer, a toll now felt even at the global level.

Fertilizer production has spurred a sharp increase in the global rate of nitrogen fixation — the process that converts nitrogen to a form usable by many living organisms. Nitrogen is now fixed at more than twice the natural, pre-industrial rate, which essentially means a boost in fertility over most of the planet. (See Figure 1.) This surge is caused by a variety of human activities, chief among them being fertilizer production, which has grown more than ninefold since 1950. Because half of the manufactured fertilizer used in human history has been applied only since 1982, the greatest surge in nitrogen (and phosphorus and potassium) levels is quite recent, and its full effects are yet to be understood.⁸

Many of the consequences of the planet's overfertilization are more pernicious than might be expected. The presence of fixed nitrogen at greater than natural levels, for example, has been shown to reduce plant diversity in prairie ecosystems at an alarming pace. In a recent 12-year

study, scientists applied nitrogen to 162 test plots of Minnesota grasslands at varying rates. The nitrogen spurred the growth of plants that were best able to take it up — but at the expense of plants that were less well adapted. Indeed, species diversity declined by more than 50 percent. This loss of diversity is consistent with the experience of parts of northern Europe, where high levels of nitrogen deposition have converted species-rich heathlands to species-poor grasslands.⁹

The loss of species diversity, lamentable in itself, also made the ecosystem “leakier,” and therefore more polluting. Because the invasive species were less able to store nitrogen than the native grasses they replaced, nitrogen leaching — an important source of water pollution — increased over the study period as the ecosystem became biologically impoverished. The Minnesota study is another contribution to the growing body of research documenting the harmful impact of excessive levels of nitrogen, once considered a relatively benign nutrient.¹⁰

Nutrient leaching can be especially high on a farm (a cropped ecosystem with little species diversity), particularly when manufactured fertilizer is used. A recently completed 15-year study by the Rodale Institute compared nitrogen budgets in three farming systems: one using manufactured fertilizer, one using manure, and the third using leguminous crops as nitrogen sources. The conventional fields leached 270 kilos of nitrogen per hectare, compared with 180 kilos on the manure-fed land, and only 110 kilos on the legume-cropped fields. Moreover, the conventional fields received relatively heavy inputs of nitrogen (a common occurrence on today’s conventional farms), much more than was taken up by crops. This combination of high inputs and high leakage — akin to opening a faucet full-force into a sieve — meant that the conventional fields lost nitrogen in large quantities. Indeed, after 15 years, soil nitrogen in the conventional fields had decreased by 11 percent, while the manure-fed fields gained nitrogen (which the soils stored for future use by crops), and the legume-fed soils kept it roughly in balance. The study demonstrates the “leakiness” of conventionally fertilized soils, and the much greater capacity of organic nitrogen amendments to increase or maintain soil fertility.¹¹

Nutrient leakage like that documented in the Rodale experiment contributes heavily to water pollution. In an aquatic equivalent of the Minnesota grasslands species losses, eroded or leached phosphorus and nitrogen promote overgrowth of algae in rivers, lakes, and bays at the expense of other species, including various fish. In fact, leached and eroded nutrients help make agriculture the largest diffuse source of water pollution in the United States. So extensive is the agricultural pollution of the Mississippi River — the main drainage conduit for the U.S. Corn Belt — that a “dead zone” the size of New Jersey forms each summer in the Gulf of Mexico, the river’s terminus. Rich in fertilizer nutrients that feed algae, the once productive area now has far fewer fish and shrimp, which cannot compete with the decomposing algae for oxygen. The phenomenon is repeated on a smaller scale around the world in countless rivers and lakes that receive agricultural pollutants.¹²

Pollution caused by overuse of nitrogen and phosphorus is also harmful to human health. Nitrates in drinking water can be converted to potential carcinogens when digested by humans, and can cause brain damage or even death in infants by affecting the oxygen-carrying capacity of the blood. The OECD lists nitrate pollution as one of the most serious water quality problems in Europe and North America. Indeed, every member state of the European Union has areas that regularly exceed maximum allowable levels of nitrates in drinking water. The problem is expected to worsen in developing countries whose fertilizer use is accelerating, such as India and Brazil.¹³

All of these front-end problems could be ameliorated to some degree if more organic wastes were recycled. Organic wastes typically contain the major nutrients supplied by fertilizer — nitrogen, phosphorus, and potassium — as well as a series of trace nutrients. And unlike fertilizer, these wastes contain organic material, which builds soil structure and creates a hospitable environment for plant roots that nurtures crop growth. At the national level, recycled organic material could supplant only a portion of total fertilizer use, because too little organic matter exists close enough to farms to provide all the nutrients needed by high-yielding varieties. But in combination with more efficient fertilizer use, organic

recycling to cropland can reduce a major source of water pollution and ecosystem degradation in countries that use fertilizer heavily.¹⁴

In some regions, however, a shortage rather than a surplus of nutrients plagues agricultural soils. Poor farmers in many African countries, unable to afford enough fertilizer, essentially mine their soils, with more nutrients leaving for cities or other countries than are returned in fertilizer or organic matter. In the worst cases, nutrients leave agricultural soils three to four times faster than they are replaced. In Sub-Saharan Africa overall, fertilizer usage is so low that it replaces only 28 percent of the nitrogen, 36 percent of the phosphate, and 15 percent of the potash absorbed by crops. Given this clearly unsustainable situation, the region would benefit from greater cycling of organic material from cities to farming areas. Systematic use of what is now considered waste material could help to keep fertilizer use on these farms from reaching the excessive levels found in many industrial countries.¹⁵

At the back end of the organic pipeline is a different series of problems, most of which are related to waste disposal. Landfills in many industrialized countries, for example, are closing at a record clip. In the United States, the 8,000 landfills in operation in 1988 had dwindled to 3,091 by 1996, as many sites were unable to comply with federal environmental regulations, and as others simply filled up. While total capacity has actually increased in this decade (because landfills are now bigger) some areas are feeling a waste capacity squeeze. For example, New York City's Fresh Kills dump — the city's last remaining landfill, and the largest in the world, covering 1,200 hectares — is set to close in 2001. City officials are drawing up plans to export their garbage, some 13,000 tons per day, to other states. Other disposal options such as incineration and ocean dumping are expensive or environmentally problematic, or are banned outright.¹⁶

Organic material forms the bulk of the growing mountains of municipal waste: 36 percent of the waste flow in OECD member states is food or garden wastes. In developing countries, organic matter typically accounts for more than half, and often more than two thirds, of the total waste stream. Besides taking up space, rotting organic material pollutes land,

water, and air by leaching acids and emitting methane, a greenhouse gas associated with climate change. New York's Fresh Kills dump emits more than 5 tons of methane and millions of gallons of acidic liquids each day; sanitation officials estimate that methane will continue to leak from the facility for 30 years after it is closed.¹⁷

The environmental costs and space needs of organic waste have raised official interest in reducing the tidal wave of trash into landfills. Several U.S. states ordered inflows to dumps cut in half by the year 2000. In the U.K., authorities are working to reach a 25 percent recycling level for household refuse by the same year. And packed landfills in the Tokyo area have led the city to ponder a garbage collection fee to discourage waste generation. Composting organic matter, on the other hand, would free up space and reduce the pollution hazards created by decaying organic material. Indeed, the state of California sees composting as the natural solution to burgeoning dumps. But the challenge is great: the state will have to compost some 70 percent of urban organic wastes by the end of the decade to meet its waste reduction goals, a hefty boost from the current rate of 40 percent (which already represents an enormous increase from recycling levels of a decade ago).¹⁸

Human excrement is another resource-turned-waste product whose disposal is increasingly difficult as urban-rural organic loops are broken. For millennia, many cultures returned human waste to soils, and a few still do today. But increasingly the material is sewerred, a disposal option that typically leads directly to landfills, incinerators, or oceans, dumping areas that are limited today or are easily polluted. The human toll from improper disposal (and from an unclean water supply, often a related problem) is intolerably high: some 2 million children die each year and billions of people become sick because of inadequate water and sanitation facilities. Yet the logical and traditional alternative — the recycling of sewage to farmland — is often unsafe because of the toxic industrial wastes that are mixed into many sewage flows.¹⁹

Disposing of waste by sewer is also water intensive and expensive. But sewers remain the disposal option of choice, despite growing water scarcity in more and more regions. The United Nations' Comprehensive

Freshwater Assessment, released in April 1997, notes that a third of the world's population lives in countries with moderate to high water stress; that share could reach two thirds by 2025. As levels of stress increase, the water needs of farmers, businesses, and households are unlikely to be met fully. Using dry methods of human waste disposal, such as composting toilets, would save a meaningful share of domestic water. These alternative sanitation technologies would also ease the strain on city budgets, since on-site systems cost only a fraction as much as sewer infrastructure. And local containment of human waste would increase the prospects for returning nutrients and organic matter to farm soils, not to mention the benefits for the health of the rivers and bays that formerly received them.²⁰

That organic recycling could have so many diverse benefits is not surprising; the problems cited here were created by the move away from a circular economy in the first place. Therein lies the good news: just as straight-line organic flows have produced multiple problems, the return to greater cycling of organic material promises a wide range of benefits. The challenge is to send the organic portion of economic activity back to its source, as was done in earlier times.

Organic Material Flows

If the flow of nutrients from farm soils were mapped, the picture would resemble a tree, with a major trunk line branching out to smaller flows as nutrients travel farther from the farm. The nitrogen, phosphorus, and potassium in Iowa soils, for example, might be taken up by corn, which after harvest becomes food or feed. Each of these products, in turn, branches out to one or more waste flows — sewage, garbage, or manure. These nutrient-laden wastes then make their way to thousands of landfills, incinerators, rivers, or bays, which may be hundreds or even thousands of kilometers from the original soils. As nutrient flows multiply and extend, the potential for returning nutrients to productive soils diminishes.

This general picture, however, varies by country. Rural economies have relatively simple and short nutrient flows — corn may be consumed only locally and only as food, for example — so returning nutrients to farm

soils is relatively uncomplicated, though often unpracticed. Industrialized and urbanized economies face greater challenges in recycling, because their nutrient paths are long and multi-pronged. Like a tree whose shape mirrors its root structure, nutrient flows tend to reflect the complexity of the underlying economy.

Crop nutrients are analogous to vitamins for humans. They assist the fundamental process of photosynthesis — the plant’s use of light energy to transform carbon dioxide and water into organic compounds that give the plant its energy. Nutrients are found naturally in soils, but nitrogen, phosphorus, and potassium — the nutrients needed in major quantities for healthy plant growth — can also be added. This is done by applying organic matter and minerals, or by spreading manufactured fertilizer, the customary practice in conventional farming. Manufactured fertilizer is essentially a collection of nutrients drawn from natural sources and processed for use on plants. Nitrogen, for example, is taken from the atmosphere and “fixed” (converted to a form that plants can use) through an energy-intensive process. Phosphorus and potassium are mined, then processed into a form that is effective for use with crops.²¹

In addition to leaving soils through harvested crops, nutrients also erode away with wind and water, or leach down to an aquifer or out to a river or lake, or volatilize in a process akin to evaporation, changing to a gaseous form. Most of this paper focuses on nutrients that leave through harvested crops. But some of the efforts to return crop nutrients to farm soils — through composting of food wastes, for example — have the added advantage of reducing erosion and leaching as well.

Accounting for all nutrient flows of all crops in all countries would be exceedingly complex. But if one focuses on grain in selected countries and regions, the essential features of nutrient movements become clearer. Grain provides more than half of the calories ingested directly by most humans, and data on grain use and trade is reliable, making grain a revealing and manageable proxy for nutrient flows in general.²²

In most countries, grain nutrients flow predominantly from farms to the nation’s own people, rather than to animals, industry, or other countries.

In developing countries, for example, more than three quarters of the grain produced is consumed domestically as food. (See Table 1.) And this share rises in less complex economies. Sub-Saharan African nations, for example, use 97 percent of the grain they grow for food. (By contrast, direct human consumption of grain in the United States accounts for only 28 percent of the total grain flows, the smallest of all U.S. grain nutrient trails.) These poorest nations produce virtually no exportable surplus, and their animals are largely pasture- rather than grain-fed, leaving nearly all of the grain harvest for domestic human consumption. This simple, rural-to-urban flow of nutrients would require an equally simple return flow to close the nutrient loop. Indeed, in most developing countries the recycling challenge is to return human and municipal wastes from cities to agricultural lands, a task made more difficult by the widespread absence of sanitation systems.²³

With greater prosperity, people tend to eat more meat, and nutrient flows become more complex as grain is diverted to animal consumption. Impoverished Sub-Saharan Africa, for example, feeds only 2 percent of its grain to animals, but in the United States, 41 percent of grain nutrients go to animal consumption. (See Table 1.) Indeed, more U.S. grain nutrients are fed to animals than are consumed by Americans, by people in other countries, or by industry. Thus, in wealthy nations, nutrient recycling involves not only human and industrial wastes, but large volumes of animal wastes as well.²⁴

Finally, some countries export a considerable share of their nutrient outflow, which complicates recycling possibilities still further. These are countries with large productive capacity relative to domestic demand, and their ranks include both wealthy and developing nations. Among the world's top seven grain exporters, which includes nations as diverse as Canada and Vietnam, exports of grain nutrients range from 12 percent to 66 percent of domestic production. Unlike flows to the domestic populace and to animals, exported nutrients are largely unrecoverable by the exporting nation, although reuse in the recipient country is possible.²⁵

In all, 10 percent of the world's grain nutrients flow across borders in grain; the figure would be somewhat higher if the grain content of

exported meat were included in the analysis. (See Table 2.) As economies become increasingly integrated, and if import dependence grows, the volume of crop nutrients crossing national borders will rise. For net food exporters, the nutrient deficit is covered by using fertilizer. But even net food importers — who are accumulating nutrients from natural sources — often resort to heavier than necessary fertilizer use because they do not recycle organic wastes, or because getting organics back to farms is too expensive or difficult.²⁶

Research from the mid-1980s that focused on a larger set of commodities gives an idea of the net regional flows of nutrients. Tracking nutrients in 15 sets of foods, including grains, researcher G.W. Cooke found a large net shift out of the Americas and Oceania and toward the rest of the world: Africa, Europe, Asia, and the former Soviet Union. (See Table 3.) Perhaps more remarkable was the relative imbalance (inflows compared to outflows) for each region. The smallest relative imbalance was found in Asia, which nevertheless imported four times as many nutrients in food as it exported. North and Central America, by contrast, exported 76 tons of nutrients for every one it imported. Cooke's data demonstrate that nutrients in food flow across regions in highly skewed quantities.²⁷

A heavy flow of nutrients in food into a nation does not mean that its farm soils are well supplied, however. Africa is a case in point. The continent takes in six times more nutrients in food than it sends out, but the soils of many African farms are steadily losing nutrients, thus exacerbating their need for imported fertilizer. Nutrients in food imports (like nutrients in domestic supplies of food) do not make their way to farm soils, but wind up instead in landfills or at the bottom of rivers or bays. Thus, even net nutrient importers turn to fertilizer to replenish their soils, or — as in many African countries — watch soil fertility slowly decline.²⁸

The use of manufactured fertilizer is the standard way to raise soil fertility in much of the world, and it is what allows large imbalances in food nutrient flows to be ignored. But fertilizer is often applied more liberally than necessary for plant growth (Sub-Saharan Africa is a notable exception), usually to ensure that crops are not underfed. Indeed, in the

United States between 1991 and 1995, close to 56 percent more fertilizer was applied to grainland soils than left those soils in crops. (See Table 4.) In China, overapplication appears to be even higher, with nearly three quarters of the fertilizer applied unaccounted for in harvested grain. Although some of the excess is building up in farmland in the short run, a large share is leached or eroded away, and is responsible for the water pollution and ecosystem degradation associated with heavy fertilizer use.²⁹

Overuse of manufactured fertilizer could be reduced and soil quality raised if nutrient outflows were reused on farmland. The “waste” flows from food, feed, or exports are all potentially circular. Food becomes human excreta or garbage, which can be returned as sewage or composted food wastes. Feed becomes animal waste, which is applied to soils as solids, as liquid slurry, or as compost. Exported food and feed can follow similar paths once they reach their destination country. And these reused nutrients can be augmented using other wastes that did not originate on the farm, such as leaves and grass clippings. As it is now, however, most of these branch paths are only partially looped back toward agricultural soils, if the loop is established at all.

The most widely recycled nutrients from crops are those in animal manure. For millennia, manure from cattle, pigs, poultry, sheep, and other farm animals has served both as a convenient and plentiful source of nutrients for plants, and as a tool for improving soil structure. Manure is still widely recycled to agricultural soils close to where it was produced. But in some countries, environmentally safe recycling is a growing challenge. As livestock operations become more centralized, manure is measured in hundreds of tons or thousands of cubic meters, and farmlands near these operations are challenged to absorb all of the waste that is produced.³⁰

Recycling of human waste varies widely by region. Many Asian nations have long re-incorporated human wastes into farm soils, but the practice is on the decline. On the other hand, recycling of sludge and wastewater is on the rise in many sewered countries. The United States and Europe recycle a quarter to a third of the sludge they produce. While increasingly

common, application of sludge to agricultural land is also controversial; sewage typically includes industrial as well as household wastes, and often contains heavy metals, toxic organic matter, and pathogens that are dangerous to human or environmental health. Thus the growth in recycling of human wastes is not always a positive trend.³¹

In many countries, municipal solid waste is a readily available but largely untapped source of nutrients and organic matter that could enrich soils. Organic material accounts for more than a third of urban wastes in industrialized countries and well over half in many developing countries. Only a small portion of this material is returned to soils: OECD member states composted just over one tenth of their organic wastes in the early 1990s. In developing countries, the potential for recycling is also largely unrealized.³²

Greater reuse of organic matter on farms will not eliminate the need for outside sources of nutrients. Extensive nutrient losses are inevitable. The share of nitrogen in manure or sewage that is returned to the atmosphere through volatilization, for example, can be large — even as much as 50 percent (although these losses can be minimized through careful management of wastes). In addition, the high-yielding crop varieties in use today require more fertilizer than native varieties did. Still, reuse of organic matter can reduce the need for manufactured fertilizer while building soil fertility and health. In the process it can also help solve a surprisingly wide array of problems, from leaching and erosion to waste disposal.³³

Composting Urban Wastes

The world's cities generate tons of natural wealth daily in the organic garbage — food scraps, yard trimmings, and paper wastes — that every household and many businesses and institutions throw away. This garbage is rich in organic matter — an essential ingredient for healthy soils — and it contains a modest supply of plant nutrients. Instead of exploiting this resource, however, most cities are intent on burying or burning it, or dumping it into rivers, lakes, or the sea. But as the benefits of reusing such material become evident, more cities are reclaiming it. To

do so, they are turning to an ancient practice — composting — as a natural way to prepare the “waste” for reuse.

All organic materials contain both organic matter and nutrients. But working raw organic materials directly into the soil is not always the best way to exploit its organic matter and release its nutrients. Nutrients in materials that decompose slowly, for example, are “locked up” and unavailable for plant use. And in some soils, decaying organic matter can tie up soil nitrogen that would otherwise fuel plant growth. Fortunately, organic material can be converted — through composting — to a stabilized product that builds soils and releases nutrients in a steady and environmentally healthy way. Composting is a several-month-long process in which bacteria, worms, and other organisms feast on piles of carbon-rich matter and digest it, leaving behind humus, a rich, stable medium in which roots thrive. Worked into farm soils, humus builds soil structure and provides a productive environment for plants and essential soil organisms.

The ingredients for compost can come from a variety of sources. Food scraps, yard trimmings, paper, and sewage are all compostable, but most of this material is currently discarded. Food scraps and yard trimmings alone account for more than a third of the municipal waste flow in industrialized countries and well over half in many developing countries, which can afford fewer throwaway items. (Low-income countries have relatively small waste flows, but a large share of these flows is organic waste.) Yet, like OECD member states, most countries return only a small portion of this material to soils. (See Table 5.)³⁴

If paper is included in the analysis, the compostable share of municipal solid waste jumps to more than 50 percent in industrial countries. Paper is best recycled into paper, not compost, but under certain conditions it is appropriate for composting. Where organic material is deficient in carbon, for example, paper can be added to raise its level. And when the market for recycled paper is saturated, composting paper can help to maintain the value of recycled paper. Had surplus paper been composted in 1996, when recycling centers were inundated, it would have stabilized

paper prices and eased pressure on landfills and incinerators — in addition to returning organic matter and nutrients to farm soils.³⁵

Beyond its contribution to waste reduction, the long-run value of compost lies in its capacity to build soils. Because it is riddled with pores, the humus in compost shelters nutrients and provides extensive surface area to which nutrients can bond; indeed, humus traps three to five times more nutrients, water, and air than other soil matter does. These characteristics also help retain nutrients that could otherwise be leached or eroded away. Thus, adding organic matter to soils further reduces the need for additional nutrient applications.³⁶

Another important contribution of compost — suppression of plant diseases — has only recently been extensively documented. Since the 1970s, field tests have shown that compost limits the spread of root rot as effectively as many fungicides. Indeed, horticulturalists have found that compost in potting mixes makes fungicidal drenches largely unnecessary. Harry Hoitink, a plant pathologist at Ohio State University and a pioneer in disease suppression research, asserts that compost use by nurseries in Ohio has eliminated the use of methyl bromide — a potent fungicide highly poisonous to humans, and an ozone-depleting substance whose use is soon to be banned. Because chemical alternatives to methyl bromide are less effective or are also unsafe, the disease-suppression capacity of compost is welcome news. Scientists are now learning to augment this capacity by inoculating compost with beneficial organisms.³⁷

Compared to its advantages for soil building, water retention, and disease suppression, the nutrient contribution of composted urban organic material is modest, but significant nonetheless. Nutrients in municipal solid waste (not including paper) in OECD countries amounted to an average 7 percent of their commercial fertilizer use in the early 1990s. (See Table 6.) Because fertilizer is commonly overapplied, however, the potential contribution of urban nutrients is actually larger than the 7 percent figure indicates. If fertilizer use in OECD countries were reduced by a third — less than the rate of nutrient overapplication in many industrialized countries — nutrients in solid waste would amount to 12 percent of nutrients applied as fertilizer. This level of nutrients (which

does not yet include those available from human waste) begins to offer potential for cutting the pollution of water caused by fertilizer overuse.³⁸

How much reduction in fertilizer use is allowed by incorporation of compost depends on the makeup of the compost, the amount applied, soil and climate conditions, and the crops being cultivated. Compost can reduce fertilizer use because of its own nutrient contributions, but also because of its capacity to reduce leaching, which allows a greater share of applied fertilizer to be used by plants. On the other hand, the fact that compost releases its nutrient supply very gradually (unlike fertilizer, whose nutrients are immediately available to plants), only allows the full nutrient contribution of compost to be realized over time, after soils have been built. Still, compost use has already led to reductions in fertilizer applications in some areas. According to a World Bank report, for example, farmers in India who use a commercial compost called Celrich cut chemical fertilizer consumption by some 25 percent.³⁹

Finally, composting is accessible to people who are poor. Because it is a decentralized and natural source of wealth — every household produces composting ingredients — it can promote better nutrition among the urban poor who cultivate their own food. An estimated 200 million city dwellers worldwide now practice urban agriculture, supplying part of the food needs of some 800 million people. In Kampala, Uganda, for example, 35 percent of households produce their own food. And in Accra, Ghana, urban residents supply the city with 90 percent of the vegetables consumed there. For the urban poor, compost is a virtually free fertilizer and soil builder, whose production requires little space, virtually no equipment, and a modest amount of labor. Such a valuable and affordable resource, available without reliance on outside suppliers, can make a large economic and nutritional difference to people living on the economic margins.⁴⁰

For all its wonders, compost presents some important managerial challenges. Composts vary from place to place — and even from batch to batch — because the combination of inputs can vary so widely. Yard clippings are more available in summer than in winter, for example, and their nutrient make-up changes with the seasons. Paper availability may

depend on the ups and downs of the economy. The good news is that this complexity allows composts to be tailored to the particular soils and crops they will serve. But it also requires that compost makers know their customers and respond to their diverse needs, and that users understand how the product works in soils. Creating the right compost for a particular use and employing it optimally will require more research and outreach than is typically available today.⁴¹

As the many advantages of composting become apparent, its practice is taking off. In the United States, composting facilities multiplied more than fourfold between 1989 and 1996, from some 700 to more than 3,200. Many cities and counties now make organic matter available to the public for use as mulch, or as the feedstock for compost making. In San Jose, California, a recently completed three-year pilot program to promote the use of compost led to a 54 percent increase in its production by local processors, and demand for the product was brisk.⁴²

Compost is increasingly recognized as good business. Evidence of this is the experience of Community Recycling of Southern California, which saw gold in the spoiled fruits and vegetables of area supermarkets. The company mixes the produce with yard wastes from the area to generate 125,000 tons of compost per year — the maximum allowed under its permit. Today, the two largest supermarket chains in southern California, representing more than half of the grocery outlets in the region, have their organic wastes composted by this firm.⁴³

Community Recycling is not the only beneficiary of its organic recycling program. The compost is spread over some 12,000 hectares of farmland, whose soils enjoy the multiple benefits of higher levels of organic matter. Farmers profit directly too: the company calculates that nutrients in one ton of its compost would cost \$58 if purchased as fertilizer. But the company sells its compost for \$10 per ton.⁴⁴

Composting also has economic benefits for institutions that generate organic waste. Some schools, prisons, hospitals, and other food-serving establishments save money by having food scraps composted instead of hauled away for disposal. Middlebury College in Vermont, for example,

reports annual savings of some \$25,000 by sending food residuals to a compost facility rather than to a waste disposal operation. The New York State Department of Corrections has saved more than \$1 million by composting food scraps at 31 sites around the state. The key is for composters — whether individual farmers or large, centralized operations — to charge less to accept the organic material than a landfill or other disposal destination would. The generator of the waste saves on disposal costs, and the composter receives revenue to haul away material that will be transformed into a profitable product. The “win-win” possibilities of composting are indeed extensive.⁴⁵

Such mutual advantages, however, are not automatic or guaranteed. The Indian government, for example, has tried several times in recent decades to promote composting of municipal wastes, but the schemes have largely failed, for various reasons. Inputs to the composting process were not well monitored, and inclusion of non-organic material lowered the quality of the resulting compost. Poor equipment maintenance led to breakdowns and inconsistent production. City governments were seldom committed to the federal government’s vision of widespread composting. And subsidies on fertilizer made compost economically uncompetitive. While the potential benefits of composting are manifold, the Indian experience demonstrates that effort is required to avoid a number of potential pitfalls.⁴⁶

It is ironic that composting, so lately embraced in many economies, is one of the oldest forms of recycling known to humankind. As societies become reacquainted with this practice, its value as a natural solution to problems from overflowing landfills to anemic soils will become apparent. Then, with the proper institutional and economic incentives, composting could become as commonplace as the recycling of cans, newspapers, or paper is today.

The Potential and Peril of Human Waste

Most of the world’s cultivated food passes through human beings, so it is no surprise that human waste is a trove of nutrients and organic matter. Harvesting this material for agriculture is a natural way to close an

important organic loop; indeed, Chinese farming thrived on recycled excreta for thousands of years. But as more cities process these wastes using technologies designed to dispose of them, rather than reuse them, safe recycling of human waste becomes much more difficult. Safe reuse is best ensured by shifting away from disposal technologies — such as conventional treatment plants, or sewers that mix industrial and domestic waste — and toward technologies engineered to produce a clean fertilizer. For countries not yet committed to expensive disposal systems, this shift can occur more quickly than for those that are. Until such a shift takes place, the reuse of human excreta can be safely practiced only by observing the strictest standards.⁴⁷

Most excreta is not reused, although reuse — often unsafely practiced — is growing. In developing countries, where 72 percent of the population has access to adequate sanitation, sewers, septic systems, and pit latrines are the dominant disposal systems. Sewers and septic tanks predominate in Latin America and the Middle East, while Africans and Asians rely at least as heavily on pit latrines. Most sewers flow to the nearest river, bay, or ocean; only 10 percent of this sewage receives treatment. Where pit latrines are used, waste material typically remains buried. Except for parts of Asia, which has a long history of excreta reuse, and some arid regions, where sewage water (often untreated) is commonly used for irrigation, human waste is widely regarded as unwanted debris.⁴⁸

Industrial countries have long had the same perspective, but this is changing. Many now encourage reuse of sewage sludge on farmland, and the practice is growing. European countries applied roughly one third of their sewage to agricultural land in the early 1990s, while the United States applied 28 percent. The growing interest in reuse may reflect dwindling options for cheap disposal, rather than a strong interest in building farm soils. Traditional dumping sites — landfills, incinerators, and oceans — are less available, more costly to use, or legally off-limits today, while farmland is often an inexpensive alternative disposal site. But just as sewers and treatment facilities are not designed for recycling, farmland is not suited to absorb the chemicals and heavy metals often contained in the sewage stream.⁴⁹

If human wastes are made safe for use on farmland, however, their reuse can help reduce applications of chemical fertilizer. In many developing countries, the nutrient content of human waste is equal to a substantial share of the nutrients applied from fertilizer, even after losses of nitrogen to volatilization are taken into account. (See Table 7.) For OECD countries, nutrients in human waste that is not already spread on land equal roughly 8 percent of the nutrients applied as fertilizer. As with municipal organic waste, this figure understates the potential contribution of nutrients in human waste. If fertilizer use in OECD countries were reduced by a third, nutrients in human waste would amount to 12 percent of nutrients applied as fertilizer.⁵⁰

Recycling human waste, however, will require different technologies, or different ways of using existing ones. Modern methods for disposing of human waste are not designed for reusing it. Sewers, for example, commonly serve residences and industry together, a practice that often contaminates organic matter with heavy metals or toxic chemicals. Conventional treatment plants are designed to remove nutrients (and other matter) from wastewater, which lowers the enrichment level of effluent used for irrigation. Moreover, conventional treatment methods (with the exception of disinfection, which is rarely practiced in developing countries) reduce pathogens by too little for safe reuse in agriculture. Thus, many of today's disposal technologies are not suited to produce fertilizing products.⁵¹

Where sewers and treatment plants have been turned to waste reuse, there have been mixed results, at best. Even in countries considered successful with reuse — Israel, for example, which diverts treated wastewater to irrigation — caution is warranted. The country began large-scale reuse of sewage effluent in 1972, and today recycles 65 percent of its wastewater to crops. No excessive rates of illness have been linked to its use. Nevertheless, cadmium levels have been shown to increase by 5 to 10 percent annually in Israeli effluent-fed soils, and heavy metals were found to have accumulated in an aquifer below land that was irrigated with effluent for 30 years. If industrial wastes were not dumped in sewers, the country could more safely apply sewage effluent to crops. Better yet, if human wastes were managed using dry (non-sewered) methods such as

composting toilets, the water currently used to carry sewage would be available to agriculture as clean water.⁵²

Where sewers are little more than feeder lines to irrigation canals, and where the sewage they carry is untreated, risks to human health are much greater. Raw sewage used to irrigate vegetables and salad crops is blamed for the spread of worm-related diseases in Berlin in 1949, typhoid fever in Santiago in the early 1980s, and cholera in Jerusalem in 1970 and in western South America in 1991. Even so, the risky use of wastewater continues in many developing countries. In the Mexican state of Hidalgo, wastewater from Mexico City is used in the world's largest wastewater irrigation scheme, covering some 80,000 hectares. The effluent, which is 55-80 percent raw sewage (the balance is storm water), is barred from use on some salad crops, but other foods, including corn, wheat, beans, and some vegetables, are irrigated with sewage water.⁵³

In contrast to wastewater reuse, application of sludge to farmland carries a different set of risks, especially where industrial wastes or household chemicals are part of the sewage flow. Researchers from Cornell University and the American Society of Civil Engineers have found more than 60,000 toxic substances and chemical compounds in U.S. sewage sludge, and report that 700-1,000 new substances are developed every year, some of which also enter the sewage stream. These substances include PCBs, pesticides, dioxins, heavy metals, asbestos, petroleum products, and industrial solvents, many of which are linked to ailments ranging from cancer to reproductive abnormalities. They are also a threat to soils: once introduced to cropland, for example, heavy metals persist for decades (as in the case of cadmium) or even centuries (as in the case of lead). Because little control is exercised over what enters sewers, the contents of a given load of sewage sludge can be highly unpredictable and potentially dangerous to people and soils.⁵⁴

Although industrialized nations maintain standards for sludge reuse, these may be lax. Such standards in the United States are the least stringent of any in the industrialized world, with allowable levels of heavy metals an average eight times higher than in Canada and most of Europe. Indeed, Cornell University researchers have recommended that U.S. farmers

apply sludge at no more than one tenth the levels permitted by the U.S. Environmental Protection Agency. Moreover, testing in the United States is required infrequently — as seldom as once a year for the smallest applied amounts — even though the contents of sludge can vary greatly from load to load.⁵⁵ Clearly, reliance on mixed-waste sewers and treatment plants, the “modern” way to process human waste, does not guarantee output that is safe for use in agriculture. Other technologies, most of which are simpler and cheaper than sewers and treatment plants, may offer greater possibilities for recycling wastes. Indeed, opportunities exist for developing countries to “leapfrog” past industrial nations by adopting cutting-edge technologies that are affordable and environmentally sound, and that help to close the organic loop by safely returning human wastes to agriculture.

One simple — and ancient — alternative to sewage treatment plants is waste stabilization ponds, a series of holding areas in which sewage is retained for 10 days to a few weeks. Bacteria and algae work to convert the effluent to a stable form as it passes from pond to pond. Stabilization ponds require more land than conventional treatment plants, but they are much cheaper, simpler to build and maintain, and, best of all from a recycling perspective, more effective at producing safe irrigation water. 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 — and waste stabilization ponds can achieve this.⁵⁶

One variant of the waste stabilization pond is a wetland modified to process wastes, the showcase example being the one in Calcutta. For more than half a century, sewage has been channeled to a wetland east of the city, where multiple ponds are used not only to process waste, but also to raise fish and provide nutrient-rich irrigation water for farmers. The system works by mimicking the interconnectedness of a natural ecosystem. Nutrients in the waste feed fish, plants, and organisms in the ponds. The fish, in turn, greatly reduce or eliminate algal blooms, making the final wastewater product more useful for agriculture. Water hyacinth

cultivated at the ponds' edges further purifies the water and protects the banks from erosion. And the hyacinth is either harvested for animal feed or composted. These multiple benefits, combined with a cost less than a quarter that of a conventional sewage treatment plant, have made the area a valuable municipal resource.⁵⁷

A constructed micro-version of the Calcutta wetlands system could provide waste-processing capacity for some industries, thereby preventing their wastes from entering the sewer system. Complete with plants, microorganisms, and even fish, these facilities consist of a series of pools and constructed wetlands, often built in a garden-like setting, which progressively treat industrial wastes. One U.S. 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.⁵⁸

For all their advantages, these natural filtering systems are land intensive. Stabilization ponds are estimated to require 30 hectares for every 100,000 people served. And Calcutta's wetlands system required 3,200 hectares to process roughly a third of the city's wastewater in 1991. The industry-level facilities also require an extensive area, which may prove prohibitive in crowded cities. Where land is tight, other choices are available, some of which can avoid the expense of sewage infrastructure.⁵⁹

One of the more promising options for processing human waste safely is a series of simple technologies developed and patented in Mexico and known collectively by their Spanish acronym, SIRDO. SIRDO stands for "integral system for recycling organic solid waste" and is a biochemical system that decomposes waste.

SIRDO technology is applied 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. Solar heating and bacteria transform wastes and other carbon matter into a safe and odorless "bio-fertilizer" that is sold to nearby farms.⁶⁰ A bacteria used to accelerate the treatment process

is collected from the remaining soil of "Chinampas" (a.k.a. "floating gardens), an indigenous agriculture system used by the Aztecs in lagoonous regions of Mexico. In the SIRDO, household organic matter is composted together with human waste, thereby easing pressure on landfills and sewage treatment plants. "Wet" SIRDO units are neighborhood-level mini-plants that biologically process the wastes of up to 1,000 people. They can operate in conjunction with existing flush toilets and local sewer lines. Even these "wet" systems are water savers, because they 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 non-food crops. These systems are so simple to maintain and operate that they do not require constant oversight by an engineer. A trained lay person can handle day-to-day operations, with occasional assistance from a SIRDO specialist. Several of the wet units in Mexico City are maintained by the gardeners of the condominium complexes in which the units are located.⁶¹

SIRDO's advantages extend beyond fertilizer production and water savings. As an effective sanitation technology, SIRDO improves the level of public health by reducing illnesses caused by pathogen-tainted water supplies. In the warm climates where SIRDOs are currently used, the unit's solar-heated waste chambers generate higher temperatures, over longer periods, than are needed to ensure that pathogens are killed. In the town of Tres Marias, Mexico, introduction of SIRDO technology and a new potable water system are credited with cutting the rate of gastrointestinal illness from 25 cases per person in 1986 to less than one case per person in 1990. Since contaminated water is a major cause of sickness and death among children in developing countries, the technology's success in sterilizing wastes is a welcomed advance.⁶²

Moreover, the SIRDO systems are affordable, and they even generate modest flows of revenue. A cost-benefit analysis undertaken by the National Wildlife Federation (NWF) found that all five SIRDO models studied — three wet and two dry — offered net financial gains under Mexican market conditions for water, labor, and bio-fertilizer. The simplest dry design, for example, costs \$200 under (including set-up) and \$20 per year for maintenance — a total of \$500 over 15 years — but

earns the owner \$2,000 in fertilizer revenues in the same period. The net income for user families is modest — on the order of \$30-60 dollars per year — but nonetheless meaningful for people living on the economic margin.⁶³

Significantly, the NWF analysis was limited to private costs and benefits. It did not consider the technology's social benefits, which include the reduced need for sewage treatment, boosted levels of public health, and improved soil structure and fertility on farms that use the bio-fertilizer. SIRDO's multiple advantages to users and society have spurred its adoption in Guatemala, Chile, and seventeen states in Mexico.⁶⁴

Another non-sewer approach to waste processing doubles as a source of energy. Since the 1970s, China has installed more than 5 million anaerobic digesters — large chambers, sitting mostly underground, that break down a rural family's organic waste, including manure, human excreta, and crop residues, producing gas in the process. Toilets and pigsties drain directly into the digester, which yields enough biogas to meet 60 percent of a family's energy needs, mostly for cooking and for fueling gas lamps. The unit also produces an odorless dark slurry, used primarily for fertilizer, but also viable as feed for livestock or fish. The digesters are inexpensive — \$80 covers the cost of materials and the help of a technician in construction.⁶⁵

In cities that are already sewered, and whose populations are accustomed to flush toilets, separation of human and industrial wastes will be more challenging, and may need to be viewed as a medium- to long-term goal. Nevertheless, current technologies suggest several possible approaches. Dry composting toilets, for example, can be installed in the bathrooms of many suburban homes. They look like standard flush models — without the water tank — and can hold up to several years' worth of excreta. They require some maintenance, including occasional additions of carbon material, such as sawdust or leaves, and periodic inspection of the equipment and the compost itself. Service contracts, however, can minimize the burden on homeowners. Other non-sewer technologies include micro-flush toilets, which use as little as one pint of water per flush, and vacuum-powered toilets similar to those in aircraft lavatories.

All of these systems create a fertilizing product that can be applied to home gardens or, where economically feasible, collected and sold to farmers. And because the excreta is segregated from the flow of detergents, cleaning products, solvents, and other chemicals used in many households, the composted material is clean. The systems are not cheap, however, ranging in price from \$1,000 to \$6,000 per unit.⁶⁶

Large buildings, such as multi-story apartment complexes, would be served with different technologies. (Dry composting toilets usually require that the holding chamber be located directly below the toilet, which makes their use in multi-story buildings impractical.) Constructed wetlands are one possibility for buildings that have plenty of land. A more viable option is the use of biogas digesters, similar in concept to those used by some Chinese peasants, but built on a larger scale. Located in the building's basement, the digester would collect wastes from standard low-flush toilets and produce two products: methane, which could provide part of the building's power, and uncontaminated sludge, which could be collected and applied to farmland. Digesters offer a glimpse of the multiple benefits possible from full exploitation of human "waste."⁶⁷

The nutrients in human waste constitute a vast, untapped agricultural resource. Getting them safely back to farmland would help to build soils and reduce the need for additional nutrients from fertilizer. But separating human excreta from industrial wastes — the prerequisite for safe recycling — will require imagination and commitment. Ironically, unsewered cities may be in the best position to capitalize on new technologies for excreta management, technologies designed to produce an uncontaminated fertilizer product.

Sustainability and Scale

Fertilizer and cheap transportation were the original scissors that snipped open organic loops, thereby unleashing the pollution and waste problems described earlier. Today, the globalization and concentration of agriculture compound these problems by stretching and fattening nutrient flows. The surge in agricultural trade, for example, redistributes nutrients

unevenly around the world, driving some regions to a heavier-than-necessary dependence on fertilizer, and leaving others with unhealthy nutrient surpluses. And concentration of production can swell nutrient streams until nutrient accumulations become unmanageable. The emerging lesson is that scale matters, and that too large a scale can lead to distortion and mishandling of nutrient flows. Even the scale of recycling operations can determine whether cities are successful in actually closing nutrient loops. Prospects for restoring circularity to organic flows may depend on limiting the scale of agricultural operations and some recycling operations so as to shorten and unplug today's linear movements.

The globalization of food flows may be the sleeper agricultural story of recent decades. The last 40 years are widely heralded for their unprecedented growth in output, but agricultural trade — and the displacement of soil nutrients that trade entails — grew even faster than production. World grain output, for example, doubled between 1960 and 1995, but grain exports tripled during the same period. Indeed, growth in agricultural trade has outpaced production consistently since 1960, except for a short period in the mid-1980s. Today, more dinner plates are filled with food of distant origin, and more nutrients cross national borders, than ever before.⁶⁸

The uneven redistribution of food nutrients resulting from increased international trade generates net losses in some areas, and net gains in others. Several countries in northern Europe, for example, suffer from excessive accumulations of nutrients, many of which are imported across oceans. An extensive European livestock industry purchases feed from as far away as Brazil, Thailand, and the United States. But the industry has outgrown the capacity of nearby lands to absorb its wastes, so manure has steadily accumulated. Indeed, early this decade, the Netherlands could boast the world's largest “manure mountain” — some 40 million tons' worth.⁶⁹

These accumulations, coupled with heavy fertilizer use, are responsible for serious pollution problems in the Netherlands. Nitrate levels in the country's groundwater were more than double the recommended maximum level in the early 1990s. So saturated was the country in

nitrogen and phosphorus at mid-decade that farmers could have met their crops' nutrient requirements from manure alone — without a single application of nitrogen or phosphorus fertilizer — and still ended up with a nutrient surplus in their soils. The mismatch between the scale of activity — heavy flows of nutrients from three continents that converge on a single small region — and the environment's limited capacity to absorb the output of that activity demonstrates the relevance of scale. The inflow of nutrients to the region was so large that they could not be recycled there, nor could they be returned to their original soils.⁷⁰

Taiwan finds itself with similar problems, after building a substantial, but import-dependent, hog-raising industry. The country buys more than 90 percent of its corn feed from farmers in the midwestern United States, an ocean and half a continent away. But the oversized hog-raising industry produces more manure than the country can handle, resulting in extensive pollution, as in the Netherlands. Indeed, officials in Taiwan estimate that two thirds of Taiwan's water pollution is the result of manure discharges from hog farms. As a result, the government has been struggling since 1991 to reduce the number of hogs by one third.⁷¹

Lengthened nutrient supply lines are also found within countries. This is especially clear in the United States, where feed is shipped ever greater distances as cattle-, hog-, and chicken-raising facilities move away from feed production regions. Cattle feedlots, for example, were once located in the Corn Belt states that supplied them with feed, but they began to move hundreds of kilometers west to the Great Plains in the 1950s and 1960s. More recently, hog production has shifted hundreds of kilometers east, from the Midwest to Virginia and North and South Carolina. The supply line connecting feed and livestock, which once extended a few hundred meters from field to barnyard on a single farm, has now been stretched across state lines, essentially precluding the return of nutrients to feedcrop fields.⁷²

The separation of livestock from crops is linked to another issue of scale, the size of agricultural operations. Large operations realize economies of scale that allow them to absorb the transportation costs resulting from long-distance food and feed shipments. Not surprisingly, then, the shift of

livestock production away from feed-producing regions in the United States was accompanied by an increasing concentration of operations. (See Table 8.)⁷³

As livestock operations have centralized, however, so has manure, creating a waste disposal dilemma where farmers once saw only a resource. Indeed, facilities with tens of thousands of animals measure their waste production in hundreds of tons of manure or thousands of cubic meters of slurry. The slurry lagoon on one mega-farm in Missouri, for example, covers 2.8 hectares, is 5 meters deep, and holds more than 87,000 cubic meters of effluent. Such large accumulations of waste cause serious environmental damage: the U.S. Environmental Protection Agency reports that effluent from centralized livestock facilities accounts for more than a quarter of the water pollution caused by agriculture in the United States. In North Carolina alone, over half a dozen major lagoon spills were reported in 1995, including one involving some 95,000 cubic meters of lagoon effluent.⁷⁴

The buildup of nutrients from large animal-raising facilities has been documented in several states. In Delaware, for example, farmers were applying 72 percent more nitrogen and phosphorus than their crops needed in the early 1990s, thanks in large part to heavy use of manure from the state's extensive poultry-producing operations. Without enough cropland to absorb the mountains of manure generated each year, the material is applied wherever possible, at a rate of overapplication that averages some 50 kilos per hectare. The manure generated by poultry could meet well over half of the state's crop nutrient needs if it could be easily and economically distributed, but large, centralized operations make this difficult.⁷⁵

The case of burgeoning livestock facilities demonstrates that operations can be too large relative to the absorptive capacity of the surrounding environment. In other cases, operations are too large relative to a region's base of technology or skilled labor. In many developing countries, for example, composting municipal solid waste is more likely to occur — and recycling is more likely to be realized — if it is pursued in a decentralized way. Centralized facilities often require expensive imported

machinery, which eliminates jobs and requires technical skills that may not be available. Neighborhood-level composting, by contrast, requires less capital investment, creates more jobs, and can use simple methods that rely on nature to do the composting work.⁷⁶

Consider the history of composting in India. Despite a commitment by national governments as early as 1944 to increase composting and recycling in major Indian cities, most initiatives have been spectacular failures. Projects were designed to handle large quantities of organic material — between 150 and 300 tons per day — and were supplied with imported machinery for large-scale processing. But the machinery was poorly maintained and workers were inadequately trained. Moreover, the garbage fed into it contained large amounts of non-organic material — 70 percent of the compost ingredients in Calcutta, for example — which damaged machinery. These problems raised operational costs, and with little effort to market the final product, cities soon found themselves operating financial sinkholes.⁷⁷

Small-scale, low-tech composting efforts in other developing countries offer an encouraging contrast to the Indian experience. The city of Coimbra, Brazil, for example, wanted to reduce inflow to its dump, which was leaching contaminants into a stream used for irrigation and as a water supply for animals. Using local materials and local labor, the city built a simple facility that could process 15 tons of waste per day. Twelve handcarts and three animal carts collect refuse daily from the city's 7,000 residents. The organic material is then manually sorted and composted naturally in various piles at different stages of maturation. The center produces more than 12 tons of compost per month from waste that would previously have been buried. More important, the labor-intensive composting process provides work for eight people — five of whom had lived and worked as scavengers at the landfill.⁷⁸

A still more decentralized process is used in Cairo by the Zabbaleen, a group of poor Coptic Christians who survive by collecting garbage from wealthy neighborhoods and using it as feed for pigs, which are raised in enclosed courtyards throughout the city. The Zabbaleen deliver the manure and other organics to a local composting facility. Because the

manure is already partially decomposed, composting time is greatly reduced, to a week or two. The resulting compost is coveted by farmers within a 100-150-kilometer radius of Cairo, who pay for its delivery. The product is not perfect — it often has high levels of lead and zinc — but an effort to have households separate their organic garbage from other wastes before it is collected could largely eliminate this problem.⁷⁹

The question of scale is often treated solely as an economic issue. From this limited perspective, bigger is better, because economies of scale typically make large operations more competitive than small ones. But equally relevant are “ecologies of scale,” under which larger operations may be more environmentally damaging because they reduce the possibilities for successful recycling. These ecologies of scale provide a more complete picture of the costs and benefits of large, centralized operations.

Returning to Our Organic Roots

As the drawbacks of today’s linear organic flows become evident, interest in recycling organic material is growing. But a return to time-honored recycling practices is not simple in an increasingly urbanized and industrialized world. Many economies are deeply invested in linear flows of organic matter, and will require time to reestablish organic loops. They will also have to wrestle with fundamental issues of sustainability, including the maximum sizes of viable cities and agricultural operations, and the maximum extent to which food should be traded and food raising should be concentrated. But commitment to a series of five principles of organic matter management is a good first step; from these principles, specific policies can emerge to close the loop.

The baseline precept for organic matter management is this: in a fully sustainable world, all organic flows must cycle. By this *first* principle, any instance of organic dumping — whether of garbage sent to a landfill or incinerator, sewage flowing to a bay, or manure overapplied to farmland — represents unacceptable waste of a natural resource. Just as policymakers and citizens would not tolerate the wanton burning, dumping, or burial of natural resources, neither would they allow organic

matter to be casually discarded if they saw its true value. Appreciation of the contribution of organic matter to sustainable urban living will require a diverse set of policies affecting the individuals, municipalities, and industries that produce organic waste and the farmers that use it.

As a starting point, organic material can be turned away from traditional disposal sites using taxes or legal restrictions. The U.K., for example, has instituted a landfill tax designed to discourage landfill use, while several U.S. states have mandated cuts in organic inflows to landfills, or bans on particular kinds of organic matter, such as grass clippings. The U.S. has also banned ocean dumping of sewage, and Europe is set to do so as well. Each of these diverse policies closes another door on organic dumping.⁸⁰

Outlawing dumping, however, is only half the battle. Viable recycling options are necessary to ensure that material is actually reused. Such options are best governed by two more principles (the *second* and *third* principles of organic matter management). It is a principle (our *second* one) that organic wastes should be segregated from other wastes. It is generally simpler and cheaper to prevent contamination of organic material than to try to clean up dirty material. Segregation of wastes from the beginning is the best way to do this. Once this precept is accepted, the next principle (our *third* one) can expedite the search for viable recycling options: those who generate waste must recycle it, or pay for its recycling. This variation of the “polluter pays” principle applies to individuals, businesses, and institutions alike, and spurs each to find the most efficient way to reuse material, and possibly to reduce its flow. City government can still play a large role in helping citizens and businesses to recycle, however.

Armed with these precepts, the search for viable recycling options can proceed on different levels. Municipal educational programs, for example, can equip residents to take responsibility for their food and garden wastes. Sonoma County in California has reduced landfill inflows through a citizen training program for composting, and participants have cut their landfilled wastes by an average of 18 percent. Best of all, this and similar programs are cost effective: they spend \$12 for every ton of

waste diverted, which amounts to less than 40 percent of what a landfill would charge to take the material.⁸¹

Where capital investments by individuals or institutions are required, an education program describing the potential financial gains could help to grease the wheels. Most institutions that generate large amounts of food wastes, such as hospitals, schools, or prisons, have likely given little thought to composting. Yet the experiences of Middlebury College and the New York State Department of Corrections cited earlier demonstrate that composting can make financial as well as environmental sense. Getting the word out could help jumpstart recycling by such institutions.

For human wastes, moving toward viable recycling technologies may be a long-term process, especially where cities are committed to disposal technologies. Again, education is the first step. Cities and citizens will have to determine whether their current system is capable of producing a clean fertilizing product. If not, exploration of alternative systems designed for recycling is warranted, along with plans for adoption of an appropriate technology. In developing countries — many of which need to invest in construction or maintenance of sanitation systems anyway — such a reassessment of sanitation represents an opportunity to leapfrog over the costly problems encountered by industrial countries with their “modern” systems. Funding limitations are cited as the chief obstacle to construction of sanitation infrastructure in low-income countries. Yet a system of composting toilets — an option that most cities do not consider — costs less than one seventh that of sewage systems. In any case, weaning a city of its sewers is not a quixotic notion. The entire province of Tanum in Sweden is converting to composting toilets, and is already enjoying the environmental benefits of the shift: nitrogen and phosphorus pollution has been reduced by 90-95 percent compared to the levels experienced when the region was sewerred.⁸²

Converting organic wastes to a useful product, however, does not ensure that organic matter will be recycled; farmers have to want to use it. One reason farmers are slow to choose organic materials over fertilizer is that they are uneasy about it. Synthetic fertilizer comes in specific formulations, with the amount of N, P, and K marked on the package

label. But compost, sludge, and manure are often highly variable products made from equally variable inputs. Farmers may be unsure of how much to apply and at what rate nutrients will become available to plants. Indeed, markets for organic matter will not mature until farmers can be confident about the product they are buying, and until suppliers can respond to the diverse needs of different soils and different crops.

This level of sophistication will require greater research into the nature and properties of organic matter, especially compost, and how these function in different soils and climates, and with different crops. But research in organic agriculture receives little official support. An innovative investigative project by the California-based Organic Farming Research Foundation determined in 1997 that just 34 of the 30,000 research projects — one tenth of one percent — funded by the United States Department of Agriculture between 1991 and 1996 focused on organic agriculture. Moreover, no provision was made for dissemination to farmers of the results of these few projects. Such institutional indifference will need to be reversed if organic recycling is to make the maximum possible contribution to agriculture.⁸³

Even if organic dumping were proscribed and farmers were eager to apply organic matter, sustainable organic flows would not necessarily be achieved. Nutrients might still accumulate in one area and be unnecessarily depleted in another. Here, our *fourth* principle emerges: budgets for nutrients should be established to keep nutrient flows in rough balance. Nutrient budgets are most meaningful at the farm level, and can be as useful to farmers as they are helpful to the environment. A simple tool known as the Nutrient Management Yardstick has been developed by the Center for Agriculture and the Environment in the Netherlands to track farm-level nutrient flows. The tool is a workbook that helps farmers to keep track of all nutrients brought onto the farm — whether in fertilizer, feed, manure, or other materials — and all nutrients that leave the farm in crops, livestock products, or other materials. Dutch farmers using the yardstick have registered reductions in nutrient surpluses in each of its six years of use, and its adoption promised to become widespread as farmers started developing mandated nutrient management plans in 1998. Dissemination of this simple tool through agricultural

extension programs could be an inexpensive way to get a handle on nutrient flows at the source.⁸⁴

Because nutrient flows are measurable, agricultural operations can be held accountable for safely maintaining nutrient balances. Indeed, any operation likely to have large on-site nutrient imbalances — like the massive nutrient inflows common to centralized livestock facilities — should have a plan for disposing of nutrient surpluses in a way that is environmentally healthy. Until a facility, for example, can demonstrate that nearby landowners are willing to receive its excess manure, and that the manure will be applied at rates that can be safely absorbed by those soils, the facility should not be allowed to expand.

Farmers' understanding of nutrient dynamics is necessary to fulfill the *fifth* principle of organic cycling: chemical fertilizer should supplement inflows of organic matter, and levels of application should not exceed the crop's capacity to assimilate it. Farmers are well aware of the nutrient content of the fertilizer they apply, but may be less knowledgeable about nutrients in other inputs to their soils, such as crop residues or manure. Those who look to fertilizer for their crop's nutrient needs sometimes apply manure simply to get rid of it, without accounting for the additional nutrients that the material adds to the soil. The resulting nutrient overload leads to pollution of nearby water. But education can prevent much of this overapplication. The U.S. state of Maryland, for example, initiated a nutrient management program in 1989 to help farmers monitor and control flows of nutrients on their farms. In just seven years, the program has enrolled well over half of the state's cultivated croplands, and nutrient overapplications on them have been reduced. In 1996, program consultants recommended an average reduction of 15 pounds of nitrogen per acre.⁸⁵

Once they internalize these principles, citizens and policymakers essentially achieve a major shift in thinking and in world view. Organic matter is no longer seen as disposable garbage, but as a soil-building natural resource. And nutrients are no longer viewed as wholly benign, to be scattered wantonly throughout the environment, but are understood to serve economies and ecosystems best when kept in balance. Such

reacceptance of the ancient appreciation of organic material will be a large step in the direction of building sustainable cities and farms.

3. The Sewage Scam: Should Sludge Fertilize Your Vegetables? *Laura Orlando*

Since the early 1990s, the U.S. Environmental Protection Agency (EPA) has been working with the waste management industry and municipalities to establish sewage sludge, the semi-solid waste byproduct from municipal sewage treatment plants, as a safe fertilizer for application on land. But a growing number of people — backed by environmental, health, agriculture, and food safety organizations — are crying foul. They say sludge is toxic and must stay out of life cycles and thus off the soil. They say the stakes are too high to wait and see if the EPA can pick up the pieces when its sludge policy comes crashing down and leaves in its wake a health and ecological disaster.

Municipal sewage treatment plants collect the domestic waste of over 75% of the U.S. population, at a cost of over \$15 billion per year to local ratepayers. These publicly owned treatment works also collect the private industrial waste from commercial enterprises and factories. In 1992 alone, local governments spent \$20 billion on sanitary sewers and sewage treatment facilities. That same year, corporations collecting and disposing of the byproducts from these facilities earned \$352 million. Since 1970, it has cost U.S. taxpayers over \$100 billion to upgrade wastewater treatment plants and extend the coverage of public treatment facilities to more households and industries.

Sewers and sewage treatment plants are big business. They are expensive to build and to maintain. No one wants to add to the price tag the landfilling of sludge, because it is the American taxpayer that will have to pay the piper. So call it a fertilizer and spread it on land. It's the cheapest option and, at first glance, the most environmentally benign and media savvy solution to an enormous problem.

For the EPA, the trouble with sludge is twofold: first, the near doubling of sewers — and therefore doubling of sludge — as a result of the 1972 Clean Water Act; and second, the 1988 Congressional ban on ocean dumping. Municipalities have enormous quantities of this material and the EPA is in charge of regulating where it can go. For the rest of us, the trouble with sludge starts with the flushing of industrial tanks and ends with an unpredictable potpourri of chemicals, nutrients, bacteria, fungi and heavy metals.

Eastman Kodak, Monsanto, Dupont, ITT, Procter and Gamble, Sun Chemical, Ciba-Geigy, Upjohn Co, James River Paper Co., 3M, the garage down the street, your neighbor's paint shop, your toilet and millions of other industries and households are connected to the network of sewers that cover this nation.

Treatment plants have various degrees of sophistication, though most in this country have the capacity for what is called secondary treatment. Sewers bring to the treatment plants whatever domestic, industrial, and commercial sources pour, flush or dump into their drains. A combination of biological and mechanical processes render the wastewater "clean," that is, it satisfies federal pollution regulations. What can be extracted from the wastewater is either hauled away in trucks to landfills or is found in the sludge. There is no magic here. What goes in has to come out. The better the treatment process is for the water, the worse the quality of the sludge.

The federal Toxics Release Inventory (TRI) attempts to keep track of toxins in the United States. The Washington, D.C.-based Environmental Working Group, in its 1996 report "Dishonorable Discharge: Toxic Pollution of America's Waters," used TRI data to estimate that 1.5 billion pounds of toxic chemicals were transferred to public treatment facilities between 1990 and 1994. 450 million pounds ended up in water bodies from the discharged "treated" wastewater. The rest — over one billion pounds of chemicals — are in the sludge, were broken down, or evaporated into the air. The Environmental Working Group believes that their numbers are "drastically underestimated."

The Resource Conservation and Recovery Act, which sets the regulations on hazardous wastes, excludes domestic sewage. If you dump your hazardous waste into the nearest river, you are breaking the law. If you dump it in the sewer, you may be doing nothing illegal. The EPA does not include so-called "transfers" of toxic chemicals to sewer systems as an official "release" of a toxic chemical into the environment. The Clean Water Act does call for some industries to voluntarily pretreat their waste — but looking at the Toxic Release Inventory numbers, it doesn't look like anyone is paying much attention to what is going down the drain.

Selling the idea of sludge as a "safe fertilizer" started in earnest after the 1988 Congressional ban on dumping sewage sludge into the ocean. The first order of business was a name change: sludge had to go, so the Water Environment Federation (WEF), an industry-sponsored organization formerly known as the Federation of Sewage Works Associations, went into action.

In 1991, the Name Change Task Force of WEF settled on "biosolids," defined as the nutrient-rich organic byproduct of the nation's wastewater treatment process. Change the name and you redraw the battle lines. It's not about sludge disposal anymore, it's about "organic" fertilizers, "biosolids recycling" and "composting." Consumers, gardeners, and farmers are confused, and rightly so.

The Water Environment Federation (WEF), whose membership is almost entirely drawn from those who have a stake in the sludge production business — treatment plant managers and operators, state and federal employees, waste management corporations, engineering firms, construction companies, and equipment manufacturers and suppliers — became the chief spokesman for "biosolids." It wrapped itself in the language of environmentalism, and locked arms with the EPA.

WEF received a \$300,000 grant from EPA to "educate the public" about the "beneficial use of sludge." Dr. Alan Rubin, who served as the chief of the EPA's sludge management branch, was loaned to WEF in 1994.

The EPA continued to pay half his salary while he became the nation's leading cheerleader for "biosolids." WEF hired Powell Tate, a powerful Washington-based public relations and lobby firm, to draw up the strategic and communications plan to push public acceptance of "biosolids." This 44-page document laid the groundwork for an all-out assault on those who question the safety of using sludge as a fertilizer.

Publications on "biosolids recycling" were churned out at an impressive speed. The level of confidence in biosolids from these publications — put out by state environmental protection agencies, industry-sponsored nonprofits, and waste management companies such as Wheelabrator Water Technologies — is unwavering. They do not flinch when they say that "the amounts of metals from biosolids application are usually no larger than those that exist naturally in soil. In fact, many of these trace metals are beneficial or essential nutrients for people. These metals are common ingredients in vitamin tablets and enriched breads and cereals" (from a Wheelabrator brochure titled "What New England Should Know About Biosolids Recycling and Land Application").

After the name change and marketing behind it were put into place, the next step in the sludge shenanigans was regulatory revision. The use or disposal of sewage sludge is regulated by the Code of Federal Regulations, Title 40, Part 503 (colloquially called "503s"). In 1992 those regulations were revised, relaxing the standards in each risk category. A 1989 letter from the commissioner of New York's Department of Environmental Protection, Harvey Schultz, to William Reilly, the head of the EPA, is an example of the kind of pressure the EPA was under to change its standards. Schultz wrote that "the City of New York found that compliance with the pollutant standards (503s) will be difficult, if not impossible to achieve for 80% of the city's sludge."

The 1992 revisions of the 503s reflected the commissioner's concerns. Acceptable cumulative load limits (accumulated amounts) increased for every heavy metal regulated by the 503s: lead rose from 110 to 265 pounds per acre, zinc jumped from 150 to 2,469 pounds per acre,

arsenic levels were raised threefold, and chromium ballooned from 467 to 2,645 pounds per acre.

With these and similar changes in the 503s, "beneficial use" (the industry euphemism for disposing of sludge on farm land) became the mantra of municipalities and industry. Cities already had been spreading sludge on land or selling it as "organic" fertilizer to gardeners and fertilizer manufacturers. Now they had a new badge to flash, one that boosted their profile and further legitimized their actions.

The 503s regulate 10 heavy metals, pathogen (disease-causing organism) levels, reporting, record keeping, application and management. Dioxins and most of the 700 to 1,000 new chemicals added annually to the 60,000 chemicals currently used by U.S. industry are not regulated. The rules are "self-implementing," meaning the government conducts no oversight, and any testing is done by the sludge producers themselves.

A 1999 publication from Cornell University's extension service recommends that farmers "limit the total cumulative load of metals in soil to no more than 1/10 the cumulative loading limits set under federal 503 regulations." Why? Because some heavy metals ingested by aquatic organisms, wildlife and humans can cause physiological mayhem: troubles like kidney disease, hypertension, liver damage, neural damage, structural change in tissues, and reproductive problems. On average, the 503 regulations for cumulative loading of heavy metals are eight times higher than those set in Denmark, Canada, the European Economic Community, France and the Netherlands.

Why the discrepancy? Europe uses "non-degradation standards" aimed at preserving farmland free from contamination for future generations. The EPA uses "risk assessments," which seem to have floating benchmarks, a high tolerance for risk, and no consideration for the synergistic effect of the chemicals in municipal sewage sludge. (Combined, some chemicals are much more dangerous than they are as individual substances.)

A panel convened by former EPA administrator William Reilly warned in 1992 that research at EPA was "uneven and haphazard." David Lewis, a microbiologist at the EPA, wrote about the agency's science 'gridlock' in a 1996 article in *Nature*, and used sludge as an example. He asserted that political pressure and court-imposed deadlines prevailed when the agency finalized its sludge rules in 1992. The regulations relied, in part, on experiments that Lewis and others labeled as "sludge magic" with little relevance to the real world.

The composition of sludge changes as often as materials are flushed into the system. On any given day, according to Cornell University and the American Society of Civil Engineers, sludge may contain any combination of polychlorinated biphenyls (PCBs), bacteria, viruses, fungi, chlorinated compounds, flame retardants (such as asbestos) petroleum products, industrial solvents, nitrogen, phosphorous, potassium, dioxin, chlorinated pesticides such as DDT, aldrin, and 2,4,-D, and heavy metals from wood preservatives, pesticides, metal plating, and batteries. These substances can be highly disruptive to life, resulting in reproductive problems, disease and death. But as with many pervasive reproductive toxins, carcinogens and persistent toxic metals in the environment, there is no smoking gun to identify the culprit.

A 1992 *Farm Journal* article calls sludge a potential "land bomb." Several farm and food organizations, including the American Frozen Food Institute and the Northeast Organic Farmers Association, are calling for a halt to the practice of applying sludge to farmland. A national grassroots effort, spearheaded by the New York-based National Sludge Alliance, to stop the land application of sludge has grown out of several horror stories from people around the country.

In Rutland, Vermont, 24 months after spreading sludge on his 99 acre farm, dairyman Robert Ruane's cows started getting arthritis, and milk production dropped from 18,000 pounds per year to 14,000 pounds per year. Over a two year period, 66 cows died. "They told me how much money it was going to save me on fertilizer," Ruane said. The municipality furnished him with two tractors, a manure spreader and a set of transport harrows. Tissue and blood samples from the dead cows

pointed to severe liver damage. But EPA labels all such evidence circumstantial.

Milk-producing cows drink up to 25 gallons of water per day. Most grazing animals also ingest soil together with their food. Any metals in the water or soil would be picked up by the liver. Since the liver's main function is to filter toxins, it makes sense that Ruane's dairy cows acted like canaries in a coal mine.

Darrell Turner, Washington State Farm Bureau President and university researcher, asks "Can you trust the analysis that you get when they are desperate to get rid of the stuff at the least possible cost?" If a farmer wants to test the sludge before it is spread, he or she can expect to pay \$250 per sample for PCBs and heavy metals and \$2,000 for a dioxin test. Once it is spread, all liability transfers to the landowner.

Municipalities transfer millions of dollars to sludge haulers like Wheelabrator, BFI and Merco Joint Ventures. It's big business run by corporations who are no strangers to bullying. When Hugh Kaufman — a champion of environmental justice and an engineer in the EPA's Hazardous Waste Division — called the transfer of sludge from New York City to the Texas town of Sierra Blanca an "illegal haul and dump operation masquerading as an environmentally beneficial project" on Michael Moore's "TV Nation," he was sued for libel by Merco, the sludge hauler in charge of the operation. Kaufman and his four co-defendants, including TriStar Television, lost the first round in court.

Kaufman and TriStar were ordered to pay Merco \$500,000 and \$4.5 million respectively in punitive damages. On appeal, the U.S. 5th Circuit Court ruled that there is no scientific consensus that the land application of sludge is safe, exonerating the defendants. Kaufman argues that this was a SLAPP suit aimed at silencing him and others like him. Michael Moore said it was about "shutting up the people of Sierra Blanca" and their call to end the sludge dumping.

If sludge is not spread on land or sold as fertilizer under brand names like Milorganite, Nu-Earth, Nitrohumus and Baystate Organic, what

should be done with it? The first step is to limit its production. Take industry off the public sewer systems and do not sewer additional communities. Safe, culturally acceptable and economical alternatives to conventional sewers exist. Use them.

The Clean Water Act mandates billions of dollars for sewerage. Instead, use this money to refine alternative technologies, and implement them on a large scale. Such alternatives include waterless and low-flush composting toilets paired with greywater recycling systems, biogas digesters and cluster systems fed to constructed wetlands. Many industries treat their own effluents and safely recycle waste, saving money and preventing environmental degradation. Encourage more behavior like this.

The second step is to safely contain the sludge that is being produced. Advanced technologies, such as gasification, an incineration process that does not produce dioxin, should be explored.

The regulators that set the levels of contamination in our environment do not differentiate between risk, which is an event with a known probability, and true uncertainty. Environmental contaminants in municipal sludge pose true uncertainty about the dangers they impart on human and ecological health. No public relations spin, earnest proclamations, regulations, recycling claims or good intentions can change that.

Future Trends

Wherever the word sanitation has been used, it has been associated with the efforts of government agencies and non-profit public health organizations. This is changing. Though sanitation has not lost its public character, it is increasingly being pushed out of the realm of public finance and stewardship in developing countries. Without laws and policies to drive sustainable practices, the private sector will do no better than governments or public institutions in providing sanitation that meets the criteria for sustainability. Developing the policy and technical infrastructure that will make sustainable sanitation possible is the topic of this section.

In his essay "Recycling Organic Waste: From Urban Pollutant to Farm Resource," Gary Gardner wrote: "The baseline precept for organic matter management is this: in a fully sustainable world, all organic flows must cycle." Organic flows are not respected in current practices, but future trends may be forced in that direction, as soil health declines and population numbers increase. Scarcity of clean water, limits to capital expenditures on sanitation, and public health threats may also move attitudes and practices into a more sustainable realm. But it is not more failures we are hoping for: it is innovation, wisdom, and the political will that will make it possible for sustainable sanitation to be made available to all people, regardless of place or income level.

Small projects have demonstrated sanitation systems that are culturally appropriate, locally responsible, and functionally sustainable. Bringing these efforts to scale will require replacing the engineering and financial infrastructure that supports sewerage with one that supports ecological innovations in waste treatment. Undoing practices that threaten to harm human health or the environment and rebuilding sanitation infrastructure from a sustainability orientation is the challenge.

Sanitation that is sustainable spends the minimal amount of energy and resources with the least loss of useable matter to contain and convert it to its usable form in agriculture. Evaluating any given sanitation system calls for a survey of energy and material inputs to useable and un-

useable outputs. How can we decide which is the optimal sanitation system for a given place? By using the concept of entropy — a concept derived from the second law of thermodynamics — to measure the relationship between waste (human and industrial), the processes and methods used to treat it, and its final disposition.

Entropy is a tool that can measure natural resources, energy, capital, and labor inputs and evaluate outputs. Sustainable sanitation utilizes low entropy systems, which minimize inputs and maximize useful outputs. Future trends in sanitation bode well if entropy becomes a consideration in policy and planning.

In this final section of the book, Abby Rockefeller looks at policy. Laura Orlando gives an outline of what could be done on a global scale and what is being done at the local level to challenge unsustainable sanitation practices. In the last chapter, Stephen Latham explores the role of microcredit in water supply and sanitation.

4. Sewers vs. the Environment: Policy for Sustainable Sanitation

Abby A. Rockefeller

Summary

Conventional wastewater treatment systems (both on-site septic systems and centralized collection and treatment) are not designed to produce usable end products. Failure to solve the overall problem of pollution caused by the waste materials received by these systems is, thus, a function of their design.

Spending resources — money, time, energy, and materials — on the extension of central treatment, either sewer lines and hook-ups or the level of treatment, should be understood to be nothing more than a waste of all those resources. The money, time, and energy should be spent instead on developing an understanding of what solving the problems now caused by these "wastes" really means and in developing a long-range plan (necessarily educational as well as technical) to accomplish this.

Public policy should set as a priority the maximization of pollution prevention, the reuse of industrial chemicals, sewage reduction, and water conservation. Only by thorough source separation can we make products out of "wastes" that are environmentally benign. Organic products that are life-compatible can then be reintroduced into the food chain. Heavy metals and toxic organic and inorganic materials can then be contained and reused within the industries from which they originated. By thus converting "waste" materials into usable products at the point of generation, we avoid the immense economic and environmental costs of central collection and treatment.

To Sewer or Not to Sewer

Given that sewage — and sewerage — is a present fact, what do we do? There are two courses open to us.

The Path Not to Take

We can continue directing all the effluent from a given sewered community to a central point where a treatment plant (as advanced as we can afford) attempts to separate (as completely as possible given the unpredictable ingredients of sewage) the water from everything else that is in the sewage. However, leaving aside for a moment the immense energy and economic costs of this option, there is the enormous though little publicized problem of the production of sludge. Simply put, the more advanced the treatment of the sewage, the more sludge will be produced, and the worse — the more unusable and dangerous — it will be. The "better" the treatment, (i.e., the more successful the separation), the greater the range of incompatible materials that will have been concentrated in this highly entropic sticky black sludge cake.

Because what goes down drains can never, either in quantity or in kind, be predicted, the chemical makeup of sewage sludge is inherently unpredictable. This has been demonstrated to be true even in the case of strict industrial source separation. There is, therefore, no such thing as safe "disposal" of sludge. If landfilled, it will contaminate the groundwater. If incinerated, it will cause serious air pollution. When dumped in the ocean (amazingly permitted by EPA until 1989), it will cause — and has caused — great harm to marine ecology.

And "land application," the latest disposal tactic, may be the most insidiously dangerous of all. Proclaiming sewage sludge to be a "fertilizer" and spreading it on farm land is, since the ban on ocean dumping, the cheapest means of disposal. This practice will certainly cause — sooner or later — contamination of agricultural soils by the toxic chemicals that have entered the sewage and come out in the sludge, which include countless non point-source toxins (e.g., from unfocused origins such as road run-off) and point-source toxins (e.g., from industries whose discharge pipes are evident). And there is,

therefore, the certainty — sooner or later — of toxic effects on crops as well as on the consumers of these crops.

Beyond direct effects on crops and consumers, catastrophic damage will be done to other life forms as persistent toxics move up the food chain. In effect, this is a highly effective way of "laundering" toxic wastes: there will be no discovery of the dumpers of industrial toxic wastes, and the polluters of the Love Canals and the Woburns will go unpunished when their wastes are hidden in farm land, in crops, and in us. In short, sludge, the product of the central treatment of sewage, is a hazardous waste, and must be recognized and treated as such.

An Interim Plan of Action

The other direction to take, the one proposed here, has two parts. First, in the thousands of communities around the country that rely on groundwater-polluting septic systems, the solution is not to sewer. Instead, Clean Water Act funds should be used to install on-site remediation technologies, of which there are a number already on the market that are technologically superior to the septic system in their ability to accomplish pollution prevention or abatement. The advantages of this sewer avoidance program are great:

- a) pollution problems can first be dealt with locally — where they begin, and where they are worst;
- b) the capital as well as maintenance costs are always much less for on-site systems than for central sewerage and treatment;
- c) most importantly, the problem of water pollution becomes solvable instead of merely movable;
- d) and, finally, development of communities is not bound to the rigid grid of sewer lines.

Second, in those cities and towns already sewerage, a back-off-the-sewer program should be implemented. That is, begin the process of

intercepting — and recovering for recycling — the resources (the constituents of what we call "waste") as close to the source as possible. This does not mean shutting down existing central treatment facilities now; rather, it means implementing a legislative mandate to fund the use of existing technologies that can accomplish separation, recovery, and recycling, at the source. The objective of this approach is gradually to reduce the range and quantity of materials entering the sewage stream, in order to decrease by degrees the burden on central treatment facilities and, thereby, the volume of sludge produced.

The implementation of such a program will, by its nature, be slow; but it can be started now on the conceptual, investigative, and legislative levels. Here are some key parts to this approach:

1. Do not extend any sewer lines to presently unsewered dwellings, institutions, or commercial facilities. Local pollution of groundwater is not, overall, more environmentally destructive than the massive relocation of pollution caused by central treatment outfalls of partially treated effluent, or the dumping, burning, and land application of sewage sludge. We must remember that, when we agree to pay for sewerage and upgrading the level of central treatment, though we may have improved the quality of a local body of water, the environment somewhere will still pay a heavy price — in direct proportion to the amount of pollution from which we have saved the water that we undertook to protect. We will have paid only to move the problem. Funds now allocated for the extension of sewer lines should instead be saved for implementation of systematic source reduction, source separation, and low-entropy resource recovery technologies.

2. Upgrade the level of treatment at those plants at which immediate protection of the recipient body of water is deemed, after full consideration of the implications, worth the economic cost and the environmental damage to be incurred by the increased creation of sludge.

3. Immediately implement a program of industrial point-source separation. Because adequate data concerning industrial processes are

readily available, it is easy to apply specific source separation techniques to industrial wastes. It is, correspondingly, relatively easy for regulatory agencies to monitor industrial discharges. The problem is political — mustering the political will to oblige each industry to pay for the collection systems and the processing systems for all the chemicals used or produced by that industry that are deemed toxic or otherwise harmful to the environment.

4. Institute a ban on the use in consumer goods of substances that are toxic or otherwise damaging to the environment. Such legislation should include mandatory reuse of toxic materials that don't themselves constitute part of consumer products, but are used in industrial processes.

5. Prohibit the use of garbage disposals. Using water to transport food wastes is as irrational as using water to transport human excreta or industrial wastes. Water should be used only for drinking and for washing.

6. Beginning at the periphery of sewered communities whose central treatment facilities are already overloaded, install composting systems designed to convert to humus — on-site — organic toilet "wastes" and food residues from kitchens. This would intercept the great bulk of organic "waste" materials at their source, preventing them from ever entering the sewage stream. Crucial to this element of the "back-off-the-sewer" plan is recognition that the products of the on-site composting toilet can — and should — be treated as useful, recyclable resources.

7. Remembering that centralized treatment of sewage creates the worst land-use conditions, start the necessary legislative work to develop environmentally sound land-use planning policies. This means putting an end to using septic systems as the de facto method of controlling development in unsewered areas.

Conclusion

Central collection and "treatment" of sewage can never solve the problem of water pollution. It will only create ever more complex pollution problems. Sludge, the product of the latest bad technocratic choice in a long sequence of bad technocratic choices, will, if permitted to be passed off as a "fertilizer," inevitably have disastrous effects both on the agricultural soils to which it is applied and on the ecosystems connected to those soils. Biologically based on-site pollution-prevention and recycling technologies are available now. These should become a federally funded choice for communities in the United States. To implement such a sewer avoidance program will require amending the U.S. Reauthorization Bill of the Clean Water Act.

5. Sanitation for the Twenty-First Century: Building Infrastructure

Laura Orlando

Why is it so hard to build sustainable sanitation systems? Do an Internet search and you will find hundreds of web sites on the topic. Volumes of well-researched papers and technical documents on sanitation have been published by organizations like the International Reference Centre for Waste Disposal, the World Bank, UNICEF, and the United Nations Development Program. Conferences are frequent. Experts abound. Still, we cannot get it right.

Part of the problem is the lumping together of water and sanitation. It makes sense that the names of the two are spoken in the same breath, since health and hygiene are related to both. But water always steals the show. It is sexier. No talk of feces or urine or odors or cultural preferences for cleansing. Delivering the product — water — is all science and no art. Measuring success in its delivery is straightforward. You see water when the spigot is turned on. Sanitation, on the other hand, is about toilets (by toilet, I mean the containment and treatment system too). You can throw hand-washing and hygiene in there, but it is essentially about keeping excreta — particularly feces and the pathogens that they can carry — out of people's stomachs.

It is a serious problem. The United Nations Development Program has declared that 3.3 billion people still lack “proper sanitation.” “Proper” here means a reduced risk of immediate disease. It means keeping out of our stomachs what comes out of our bodies and gets transported either via drinking water, food, hands, or flies. People get sick, some die, especially young children, from not having access to sanitary disposal of excreta.

Without toilets, people also have to contend with the indignity of public defecation. Lack of privacy can result in health problems for women and girls. In some parts of the world, women who live in households without toilets do not urinate until sunset, for fear of being seen. Urinary track infections are common. So is dehydration because women do not drink fluids during the day. Learning suffers too. Little girls in schools without toilets have no place to urinate, so must wait until they get home or find a private place.

The 3.3 billion figure for those lacking sanitary toilets is higher than the numbers at the end of the United Nations declared International Water and Sanitation Decade (1980-1990). In that decade, access to safe drinking water improved. The number of people on sewers increased. Funding for urban sanitation skyrocketed, with 80% of all the investments going to well-off urban areas, for expensive installations. Meanwhile latrine construction, which was the default if sewers could not be built, did not keep up with population growth.

Though coverage did not meet targets set at the onset of the program, important lessons were learned by the development sector after the ten-year focus on water and sanitation. Many new efforts are directed at doing things at the local level, and evolving a "demand-based" approach to delivering services, meaning people should get what they want and pay for what they get. That is a good idea, until one sees the paltry selection of technologies available to choose from, and the pennies available to pay for them.

Technical innovation is vital. Here we find the Achilles heel of sanitation. Make it too simple, and everyone becomes a self-described expert yet no one has expertise. Make it complex, and the engineering firms step in, spending dollars by the millions to move the problem downstream and out of sight. One can see the fingers wagging, and people saying: "But technology is not everything." Indeed it is not. But if one wants people to desire something, whether it is a television set or a toilet, you had better make it attractive and make it work. The gleaming white porcelain toilet stool in the indoor bathroom, washing away waste with one rumble of a five gallon flush, is attractive, and

works in getting rid of the objectionable material. But “getting rid of” only means making it someone else's problem. The 26 billion gallons a day of wastewater discharged by U.S. wastewater treatment plants and the resulting millions of pounds of sludge created in the treatment process do not "go away"; they merely transfer the problem to agriculture and aquatic environments.

We know what works, if "working" is defined from a health, ecological, and user-based standpoint. A sustainable waste treatment system should break the disease cycle and be free of toxins, industrial or otherwise. It should be environmentally benign at worst and beneficial at best. And people have to want it — want it in their homes, want to use it, and agree to pay for part or all of it. Not many technologies fit the bill. Compromises are bound to be made. But if we recognize that the composting toilet is a technology that meets these criteria, why is it that so few are out there and so few people can build one that works?

The composting toilet is not an isolated technology like the water spigot. It is relatively simple to make, much like a computer is relatively simple to repair. Once you get the knack for it, the devil is in the details. Where the toilet is located, how it is integrated into the living space, and what the bathroom looks like are as important as making the related treatment system watertight, ventilated, and properly sized. What happens inside the composting toilet is not magic. It is a bio-chemical process that can be moved along or impeded by some simple maintenance or lack thereof. Understanding of the decomposition process of the materials that go into the composting tank, namely feces and urine, is a fundamental building block of the composting toilet designer's acumen. Caring about what comes out at the end of the treatment process, namely humus and urine converted to its nitrate and nitrite components, is fundamental to having a good composting toilet, and ultimately defines the toilet.

Do-it-yourself construction, or auto-construction in the parlance of the development sector, is an effective way to get some on-site systems built for low-income households; but addressing the needs of billions of people with sustainable sanitation technologies will require an industry

that understands how to define good systems, how to get them into people's homes, how to get people to want them, and how to keep them working. Developing that industry means building an infrastructure that we currently do not have.

The new infrastructure consists of people approaching sustainable sanitation from a health, ecological, and user-based orientation; access to technologies that "work"; financing — both private and public — to develop production and marketing capabilities; financial packages that help people pay for the toilets; and government policies that punish polluters, reward ecological innovators, and promote demand-driven entrepreneurial initiatives in the sanitation sector.

Sustainable sanitation is about finding ways to economically and efficiently deliver the toilet you want and getting you to want the toilet that the environment needs.

6. Enterprising Technology Transfer: The Puerto Morelos Composting Toilet Project *Laura Orlando*

Summary

The ReSource Institute for Low Entropy Systems (ReSource) started a demand-driven sanitation and pollution prevention project in Puerto Morelos, Mexico in 1993, with composting toilets as its technological centerpiece. Two hundred and fifty ReSource Composting Toilets (RCTs), known locally as "Banos Ecologicos Nahi Xix," have been built in the area with local support, labor, and materials. Today, all of the units are in use and functioning properly. ReSource and its local partners are demonstrating how the technology can be delivered to rich and poor alike without losing sight of the integrity of the design of the product or its place in agriculture and in environmental and public health protection.

ReSource has demonstrated that:

- (1) the human waste management needs of communities with complex development issues and diverse household income levels can be met with RCTs;
- (2) once the technology is established, demand climbs beyond the capacity of community members involved in the model project to satisfy it without necessarily a way being found to manufacture and distribute the technology on a large scale; and
- (3) investment capital and organizational infrastructure are necessary components to extend coverage in a way that maintains quality control and minimizes capital inputs.

Puerto Morelos Project Goal

The goal of the Puerto Morelos Project is to demonstrate how the human waste management needs of Puerto Morelos, a community with complex development issues and diverse household income levels, can be met with a waste-to-resource management program that incorporates composting toilets and greywater recycling systems.

Descriptive Summary

The state of Quintana Roo has one of Mexico's most well known tourism destinations, Cancun. Its tropical climate and emerald blue water have attracted tourists since it was officially designated a place for tourism-friendly development in 1967. Today nearly two million tourists a year visit Cancun, spilling out of the confines of the city and onto the 300 km coastal corridor, called "Riviera Maya" in tourism marketing materials.

Just south of Cancun is Puerto Morelos. It is said that Puerto Morelos is what Cancun looked like 30 years ago. Its clear Caribbean water and small town feeling beckon tourists and homesteaders alike. With its mangroves, the world's second largest barrier reef a twenty-minute swim from its beaches, and an underground system of freshwater rivers underneath its limestone foundation, the town is steward to a rich and fragile ecosystem. But this ecosystem has been threatened in recent years by pollution and development. Growing in the shadow of Cancun, Puerto Morelos is struggling to avoid the rampant development and ensuing environmental degradation of its northern neighbor.

One source of pollution identified as a serious problem by local ecologists, health officials, and community members is human excreta filtering into the groundwater from latrines, septic tanks, and open-air defecation. At the request of members of the community, the ReSource Institute introduced Puerto Morelos' first composting toilet in 1993. Since then, ReSource has mapped out a strategy for installing and maintaining ecological toilet and greywater treatment systems that

prevent groundwater pollution and nutrient discharge into the coral reef and mangroves while improving public health in Puerto Morelos' neighborhoods.

Half of Puerto Morelos' 1,500 inhabitants are Mayans. The first few Nahi Xix composting toilets were built in the Mayan community, by and large the poorest of the town's diverse inhabitants. The first composting toilet in Puerto Morelos was built with local labor and materials in May 1993.

The technology has now successfully transferred from poor to rich, with the demand for it coming from people of all income levels, but most remarkably, with steady growth from eco-tourism operators and wealthier homeowners. People have found the composting toilets an excellent alternative to traditional disposal systems, easy to install on the area's rocky ground, and a powerful example of ecological development.

The RCT Project in Puerto Morelos provides hygienic and odorless toilets in geographically challenging areas, for people with sub-standard facilities or none at all, and for people who want an aesthetically pleasing and ecological sanitary facility. These facilities have been built for private homes and public facilities, for one to one hundred users. This grassroots initiative is contributing to Puerto Morelos' stewardship of its natural resources and protection of its public health.

Technology

RCTs are modeled after the Clivus Multrum-style water (micro-flush) and waterless composting toilet systems. RCTs are either built on-site or prefabricated and brought to the site. They are attractive, odorless, and hygienic -- critical factors for broad-based user acceptance.

In a self-contained composting chamber, human excreta is reduced in volume by 95% to odorless and pathogen-free compost. Urine moves through a nitrification treatment process in the composting chamber and converts to a stable and odorless, nitrogen-rich fertilizer. In experimental trials in Nicaragua, this liquid fertilizer doubled corn

yields as compared to corn that received no fertilizer, and provided corn yields equal to yields achieved through commercial chemical fertilization.

1. On-site construction

Using tested design parameters, ReSource uses available building materials and local labor to make composting toilets of various sizes and degrees of sophistication to meet local needs and conditions. All programs include training and certification of builders that lead to local construction and maintenance without ReSource's long-term participation.

A construction workers' cooperative was formed in Puerto Morelos in 1999 to build and certify RCTs. Local entrepreneurs fabricate components such as the three hatches in the composting tank, with initial technical support from ReSource. Unit costs for the composting tanks vary with materials and location.

2. Prefabrication

Prefabrication of the composting tank results in lower costs, better production schedules, and quality control. ReSource has plans to launch a commercial operation to manufacture and sell the composting toilets.

Other ReSource technologies in the project include greywater treatment systems that take used household wash-water, filter it, and return it trees and plants as nutrient-rich and pathogen-free irrigation water.

Methodology

The approach to establishing composting toilets and greywater recycling systems in Puerto Morelos includes:

- Using proven technical design parameters
- Flexibility in degrees of design sophistication (e.g., materials, size, energy needs, cost, micro-flush and waterless systems, appearance)

- Building for beauty; integrating the composting toilet into the living space, attention to detail, and standardizing the use of aesthetically pleasing components (such as natural light and ventilation in the bathroom)
- Institutionalized maintenance (not dependent on individual households)
- Community education
- An emphasis on women's participation
- Marketing and outreach (creating demand)
- Training and certification of local builders for on-site construction
- Certification of completed units
- Regional manufacturing of systems to efficiently and economically meet demand
- Support for small businesses to fabricate parts, collect and use fertilizer end-products, and perform maintenance tanks
- Outreach to government and policymakers for support, interagency cooperation, and integration into public health, environmental, and infrastructure development efforts

Beneficiaries

Project beneficiaries are primarily low-income households in Puerto Morelos and surrounding communities. Secondary beneficiaries are businesses, and middle and upper-income households in Puerto Morelos and neighboring communities seeking ecological waste management strategies for new construction.

Willingness to Pay

It has been the Institute's experience in Puerto Morelos that households are willing to pay for the RCT. Ninety-five percent of the units built in southeast Mexico have been paid for by the owners of the facilities. For the poor, creative financing schemes, such as loan funds, are sometimes necessary, paying for the composting units over time. More affluent customers pay for materials, labor, and technical assistance, as well as a technology fee, which helps support the Project. The ability to meet demand for the composting toilets is hindered not by financial

considerations, but by the lack of organizational infrastructure and limited production schedules.

Partners

Partners include:

- Community of Puerto Morelos
- Centro Ecologico de Akumal, A.C.
- Grupo Ecologista del Mayab, A.C. (GEMA)
- Luum Kanaab, A.C.
- Municipal Delegation of Puerto Morelos
- UNICEF
- State government agencies

Local Industries Supported

Local industries supported include:

- Hadzut'z-Na, S.C. (builder's cooperative)
- Sistemas Tierra, SA de CV
- Fiberglass shops
- Maintenance
- Material and hardware vendors
- Masonry workers
- Woodworkers
- Fertilizer collection and sale

Training

Training includes the following elements:

- Construction
- Maintenance — local workers and households
- Enterprise development — technical and business support

- Ecological — conferences, workshops, talks at the local schools, news media
- Public health — women's health committees, local health workers, household campaigns, school children
- Planning — city government, state government agencies, housing authorities, households

ReSource Institute

The ReSource Institute for Low Entropy Systems is an independent, nonprofit organization that supports non-depleting, non-wasting, non-polluting methods and technologies for sustainable development. ReSource has the technical capabilities necessary to address key environment issues such as water quality, the reduction of toxins, recycling, and pollution prevention. Since it was founded in 1990, ReSource has been involved in technology transfer and environmental education programs. The organization has an in-depth understanding of how to apply composting toilet technologies and develop programs in real world environments.

Enterprising Technology Transfer

When ReSource does its job well, demand for its technologies soar. It has been the organization's experience that after its educational efforts, demand for RCTs quickly outpaces ReSource's or its partners' ability to build and deliver toilets. Puerto Morelos is no exception.

If people cannot get the technology when they want it, its impact is limited. More training and increasing the number of building supervisors relieves some pressure.

Building an infrastructure that supports large volume production and distribution of composting toilets is a necessary step in the transfer of this technology. The objective is to control the deployment and development of composting toilets in an efficient and economical manner. Attracting investment capital and building organizational

capacity — whether for profit or nonprofit — will provide the fuel and the vehicle for bringing to scale the composting toilet technology.

Conclusion

RCTs represent a step forward in the struggle for clean water, a healthier population, and access to safe and effective organic fertilizers in Mexico. The technology eliminates environmental contamination by containing excreta in a sealed treatment tank, while at the same time converting materials inside the tank into safe and nutrient-rich fertilizers via a chemical-free biological process.

Appropriate technology projects and technology transfer programs should anticipate consumer demand for the product and have a plan of action to satisfy such demand ready for implementation. Understanding how to meet the demand for new technologies while incorporating traditional demands (such as the demand for aesthetic quality and simplicity in maintenance) — is critical for any program's long-term success. The organization introducing the technology must be involved long enough in to assure its place as a functional and sustainable technology.

7. Improving Water Supply and Sanitation with Microcredit

Stephen J. Latham

Introduction

Microcredit can serve as a catalyst to help the extreme poor of developing countries take active measures to maximize their access to sustainable water supply and sanitation (WS&S) services, especially in peri-urban areas. Microcredit, also called 'microfinance' and 'microlending,' is defined as the provision of small loans of working capital to the self-employed poor. Small amounts of capital, typically \$50 to \$300, can make the difference between absolute poverty and a thriving business generating enough income to feed the family, send kids to school, and build decent housing.⁸⁶

The World Health Organization has defined reasonable access to safe drinking water or water supply in urban areas as "access to piped water or a public standpipe within 200 meters of a dwelling or housing unit." Urban areas with access to sanitation services are defined as "urban populations served by connections to public sewers or household systems such as pit [latrines], pour-flush latrines, septic tanks, communal toilets, and other such facilities."⁸⁷

There is a strong correlation between those who live in extreme poverty and those who lack access to basic services, such as WS&S. Microcredit effectively pulls the poorest people out of the poverty trap, opening new avenues for them that otherwise would not have existed. Improved incomes through microcredit can provide the poor with the means to lead healthier and more productive lives, as it enables them to better afford basic services such as WS&S. However, microcredit, in and of itself, cannot guarantee that basic WS&S services are being provided to the poor. Some argue that there is a subtle question of causation; that is, whether demand for WS&S is a consequence or a cause of economic

development. Some say that the effect of improving sanitation in urban areas is to increase property values and to act as a catalyst for small business development.⁸⁸

The sad truth is that those who need WS&S services the most are typically those who lack the economic, political, and technological means to obtain it. Traditionally, those who do not have WS&S services live in abject poverty and within vulnerable geographic regions, such as peri-urban areas. Peri-urban areas — otherwise known as informal settlements, squatter settlements, slums, marginal urban communities, shantytowns, barrios and favelas — are home to an estimated 600 million people worldwide. Governments do not legally recognize many of these poor urban communities. Often they are built on land that nobody wants: on steep slopes, flood plains or near dumps. The urban fringes of Tegucigalpa are a good example. On these unsafe sites, the poor crowd into shacks made of cast-off materials.⁸⁹

Worldwide, the urban population is expected to double in 10 years, while the number of urban poor is expected to double in 5 years. According to the World Health Organization (WHO), a third of the urban dwellers in developing countries live in substandard housing or are homeless. Half of them are children. The urban poor have the worst health status — even worse than their rural poor counterparts. For example, recent studies have shown that infant mortality rates are far higher in poorer sections of many cities than in wealthier sections.⁹⁰ Although some comparisons between urban and rural areas indicate that urban health is better than rural health, those comparisons tend to be distorted by the good health of the affluent urbanites and the omission of data on the urban poor.⁹¹

Despite \$100 billion in investments, the International Drinking Water and Sanitation Decade started in 1980 to improve access to water and sanitation fell short of meeting its goals. During the decade, the number of urban people with adequate water increased about 80 percent, and the number of urban people with adequate sanitation increased about 50 percent. But the rapid rise in urban populations offset these gains.⁹²

Maximizing WS&S Coverage

Two questions need to be asked when it comes to the WS&S issue: (a) How can the provision of WS&S be maximized for the greatest number of people with the greatest need, while concurrently ensuring the quality and safety of the services? (b) How can the provision of WS&S be financed in a way that leads to the highest degree of cost-recovery and financial self-sufficiency?

A new approach is needed when it comes to addressing the old but persistent problem of inadequate access to WS&S. Microcredit initiatives can provide a viable solution to fill the gap of inadequate access to WS&S, while simultaneously equipping the poor with a viable financing mechanism to make it a reality.

The World Bank in a recent biennial publication *The World Development Report: Development and Environment* noted that not enough attention has been given to the environmental problems that damage the health and productivity of the largest number of people, especially the poor.

In the report, priorities for action included: (1) one-third of the world's population that has inadequate sanitation, and (2) 1 billion without safe water.⁹³ The effects of the lack of coverage on health are shocking, resulting in:

- 900 million cases of diarrheal diseases every year, which cause the deaths of more than 3 million children (two million of these deaths could be prevented if adequate sanitation and clean water were available)
- 200 million people suffering from schistosomiasis or bilharzia at any time
- 900 million people afflicted by hookworm

The World Bank claims that improving access to water supply and sanitation would be "the single most effective means of alleviating human distress."⁹⁴ Substandard or non-existent WS&S services have an

adverse impact on human health and productivity, impacting an individual's ability to generate income. Lack of work, as with lack of access to water and sanitation, compromises dignity and self worth, which can lead to further undesirable ramifications for quality of life on a societal level.

Impact on Poor Women and Children

Urban poor women of childbearing age are at high risk for disease and early death. Worse off are the growing numbers of single females heading households. Children of single females heading urban households are often the poorest of the poor.⁹⁵

Three myths of urbanization based on denial and defeat

It is only recently that foreign assistance agencies have begun to address urban environmental issues. The rural bias was inherent in an earlier period when the need to respond to rural issues surpassed the need to address the urban agenda. However, the rural focus should not come at the expense of addressing urban issues — especially since a substantial demographic shift is taking place from rural to urban areas. As recognized by the U.S. Agency for International Development's Environmental Health Project, three widely accepted myths have obscured and confounded practitioners in the development field for too long.

Myth number one: the growth of cities can be slowed.

The growth of cities is inevitable and unstoppable. For the next 30 years, a "tidal wave" of migrants will flood the world's cities, mostly in developing countries. By 1990, there were 1.5 billion people living in cities. By 2025, the number will swell to 4 billion.

Efforts to stop or slow the growth of cities have been largely ineffective, partly because cities are perceived as being able to offer opportunities for jobs, education, and better health. 60 percent of urban growth is attributable to babies born to people who are already in urban areas.

Myth number two: investments in medical interventions are sufficient to address health problems in cities in developing countries.

A patient-centered, cure (vs. prevention) medical approach to the growing health crisis in developing countries is not adequate. A new approach that focuses on the issues affecting families and communities is needed to weed-out the causes of illness, especially those that effect child health risk factors. Among those that need to be addressed are proactive measures such as the protection of water resources, construction of sanitation facilities, and the provision of safe water. Prevention in health is far better than offering a cure.

Myth number three: the urban poor cannot help themselves.

Although the peri-urban poor live in the geographic margins, it does not mean that they are incapable of becoming empowered and mobilizing to improve their lives. Indeed, they need help, but they are also hard workers and often exhibit considerable entrepreneurial skills. The urban poor engage in many activities, some of which contribute towards the health of the environment such as garbage collection, recycling, and rag picking.⁹⁶

Partnerships and interdependence in peri-urban WS&S

The term "linkages" is important to peri-urban WS&S because it describes the important and mutually reinforcing partnerships that must be forged, not only between the public and private sector, but among the all players — whether they work on economics, human health, or environmental quality. Because poverty is not one-dimensional, it is important to point out that linkages must also be made with other sectors that are not directly related to water supply and sanitation. These areas include education, women in development, appropriate technologies, and entities with other development agendas — particularly those relating to the quality of life.

The term "complementarity" is similar to "linkages." An emerging field of study called "ecological economics" uses the term complementarity to refer to humankind's dependence on the environment. Complementarity suggests that if factors are complements, then the one in shortest supply will be the limiting factor. By considering the inverse case, if two factors are substitutes for each other, then neither can be a limiting factor, since the productivity of one does not rely upon the availability of the other.⁹⁷ When dealing with linkages in development — whether related to health, the environment, or the economy — lack of attention to any one factor will result in a form of development that is less than optimal.

Linkages between microcredit, human health, and WS&S

Just as ecological economics recognizes the complementarity between the natural world and the human economy, microcredit, too, can benefit by recognizing its complementary relationship to human health. In the field of microcredit, one of the largest impediments or limiting factors compromising microcredit programs' ability to make sustainable economic changes for the extreme poor in peri-urban areas is the health of the people they serve. A number of diseases plague peri-urban areas, many of which are waterborne, such as diarrhea, typhoid, malaria, and cholera.

Microcredit has clearly proven to be a catalyst in its ability to address one form of poverty, lack of employment and material well-being. Furthermore, it is fairly uncontroversial that material well-being can have positive spill over effects onto other areas of poor people's lives. With more income, a family can eat three square meals a day, can afford to buy medicines for sick children, and can pay for children to go to school.⁹⁸ Providing water supply and sanitation services to the microcredit community could improve the health of millions micro-entrepreneurs and their families.

Dr. Ayela El-Bindari Hammad, former Executive Administrator of Health Policy and Development at the World Health Organization, is one of the leading advocates in international development, and

recognizes the complementarity between microcredit and human health. At the Microcredit Summit held in Washington, D.C. in 1997, she argued that wealth could not be substituted for health, nor does wealth guarantee health. If a microcredit loan recipient is not healthy owing to substandard living or working conditions, can one reasonably expect the micro-entrepreneur to fully repay his/her loan on time?

Grameen Bank and WS&S

The Grameen Bank model — unlike most other microcredit programs worldwide (a notable exception being a pilot project by Project Hope) — has recognized and acted upon the complementarities between health, access to safe WS&S, and microcredit. The Grameen Bank makes available to its borrowers loans for basic water supply and sanitation. Unlike circumstances for microcredit groups in general, the health of Grameen Bank members is significantly better than nonmembers of similar socio-economic class. Health messages are delivered as part of normal group activities at the Grameen Bank at hardly any additional cost. The inside page of savings passbooks contains a "saline poem," providing instructions for oral rehydration therapy.⁹⁹

Credit as a means, not an end

In viewing the complementarity between microcredit and health, it is useful to point out that microcredit is not an end in and of itself, but merely a means to provide access to credit for the extreme poor so that they can improve their quality of life.¹⁰⁰ It would be a mistake by the microcredit community to view microcredit as an end in and of itself. In so doing, the microcredit movement would in effect be viewing poverty as a unidimensional phenomenon, which it clearly it is not. Failing to recognize the direct linkages between human health, environmental integrity, and economic prosperity, poverty is reduced to a single limiting factor — material well-being. It is important to view poverty as a multisectoral issue, of which lack of income is but one manifestation. Other dimensions of poverty include (but are not limited to)

malnutrition, lack of education, and deprivation of women from the same opportunities enjoyed by their male counterparts.

Optimal economic allocation and WS&S

For illustrative purposes, assume that a developing country city has an efficiently run, centrally provided WS&S system. Although advocates of centralized WS&S in developing countries would argue that pipelines efficiently allocate water and sewage from source to destination, in practice it has been estimated that 40 percent of the water pumped in the network never reaches its destination owing to leakage in the pipes. Under this scenario, centralized WS&S provision is not an optimal delivery system, economically speaking.

Optimal economic scale and WS&S

Once it has been answered whether WS&S provision is optimally allocated, then the optimal scale issue must be addressed — both in terms of economic and ecological sustainability. By considering the economic dimension of optimal scale, one must ask the following questions: Can a municipal government afford to keep up with the operations and maintenance (O&M) of the current centralized WS&S system? What happens when the system is overloaded, as more people migrate to the cities than can be absorbed by the infrastructure's limitations?

Optimal ecological scale and WS&S

Following a careful consideration of the economic dimension of optimal scale, the same question with respect to the optimal scale from an ecological standpoint can be asked. Is there enough water to feasibly offer centrally provided WS&S services for all of the inhabitants of the city — not to mention those who are increasingly migrating to the urban marginal communities? Yet another question is: If the city's municipal government cannot keep pace with the current population's WS&S needs which are connected to the city's grid, can one reasonably expect the government to be able to provide for the consequent growth in the

future WS&S infrastructure needs for its residents? Finally: What should be done to accommodate the WS&S needs of the peri-urban citizen?"

A holistic framework

Four key lessons that emerged from the International Drinking Water and Sanitation Decade are: (1) Systems should respond to local demands and should be as simple, sturdy and inexpensive as possible. (2) Involvement of the community and household — particularly women — in system design and maintenance is crucial for the project to be successful. (3) Governments need to improve the efficiency and sustainability of system operation and maintenance. (4) Water should be treated as an economic commodity paid for by users.¹⁰¹ These lessons provide the foundation and the defense for using a microcredit-based approach to deliver on-site WS&S.

In reflecting on what has been said, if there is one lesson that can be derived from the previous examination, it is this: there is no single solution to the peri-urban WS&S issue. Most, if not all, problems in life are multifaceted and multisectoral. As Dr. Hammad of the World Health Organization (WHO) has said, one of the lessons one can learn from people in need is that if one wants to help them, one first needs to gain their trust and confidence. That cannot be done by disaggregating them into sectoral terms, for instance, addressing an issue exclusively as an education issue, or a health issue, or an economic issue for that matter. In short: Life is holistic.

Human beings have been compartmentalized in international development efforts. Whether dealing with the WS&S issue or any other development problem, we must think holistically about it. At the 1997 Microcredit Summit, the World Health Organization issued a statement that follows this way of thinking:

- Wealth does not equal health: increased income does not necessarily lead to automatic improvement in the health status and quality of life of individuals, family and society

- Microcredit must go beyond addressing simply economic poverty, it must consciously and directly address the multidimensional poverty that characterizes the situation of the poor and disadvantaged groups, and enable them to be responsible for promoting and improving their health status and quality of life, as well as their economic productivity.¹⁰²

Because there is no single entity in the international development field capable of addressing all forms of poverty, individual organizations that specialize in specific sectors need to find ways to build upon one another. One way this can be done is by forming strategic alliances or partnerships.¹⁰³ It is this author's proposal that a partnership be formed between the microcredit community and the WS&S sector, to provide an enabling environment that allows us to build on the linkages between microcredit, health, and peri-urban WS&S services.

Partnership between microcredit organizations & peri-urban WS&S provision

Joining hands with peri-urban microcredit networks offers a tremendous opportunity to help maximize the provision of WS&S to the peri-urban poor, while ensuring a high level of cost-recovery and financial sustainability. This is principally attributable to the fact that microcredit recipients are already familiar with credit principles. Therefore, there is no need to invest significant resources in time and money to educate or train this target population on issues such as on-time repayment, interest rates, fees, and other issues requiring a certain degree of proficiency for money lending purposes.

The urban poor are not likely to receive all of the help they need from their governments. The goal of the WS&S sector is to reach the 3.3 billion without sanitation and the one-quarter of the world's population without water. The goal of the 1997 Microcredit Summit was that 100 million of the poorest families in the world should gain access to WS&S services by the year 2005. Through these services, those families will

lead healthier and more productive lives — and the WS&S sector will get closer to meeting its objectives.

If WS&S providers are to reach the greatest possible number of microcredit clientele with WS&S services, it will require a coordinated effort at the ground level with microcredit staff promoters and the micro-entrepreneurs themselves. Normally, weekly microcredit meetings are held. At these mandatory meetings the micro-entrepreneurs may pay back their loans (in part or in full) and/or bring forward a part of their money and apply it towards savings (both individual and group). In addition, microcredit recipients may sit in to listen to a talk about the successes and failures of other micro-entrepreneurs.

The weekly microcredit meetings provide an excellent forum for a representative from WS&S organizations to talk about the benefits of WS&S services. The WS&S spokesperson could, for instance, explain how a village banker would go about obtaining a WS&S loan. Furthermore, the WS&S spokesperson could elaborate on the benefits of improved health, both for adults as well as children.

Rationale for linking microcredit organizations with WS&S providers

- Microcredit is not just a credit infrastructure, but also an adult education opportunity waiting to be utilized.
- Microcredit is an asset accumulation machine waiting to be focused on the next issue that the family really needs or really wants.
- Microcredit is a vehicle for allowing other interests to build on what microcredit has created. Microcredit can provide the place, the atmosphere, and the means to fund other development activities — such as WS&S provision.

Depending on how successful a health promoter is, s/he has a better chance of signing up more clients through the village banking network than otherwise would be possible. Reaching a broader base of clients

can have three potentially beneficial outcomes: (1) more people will be able to improve their health by living in a cleaner environment with adequate sanitation, (2) drinking water will be safer and cheaper, and (3) as more clients are drawn to the WS&S loan programs, more microcredit savings can be tapped into, which can then be applied to WS&S projects.

Implications of a WS&S/Microcredit partnership

A broad-based microcredit/WS&S partnership clearly has the potential to generate substantial dividends for both sides. The implications are as follows:

- WS&S providers can derive a larger client base from its partnership with microcredit organizations.
- WS&S clients (the peri-urban poor) can gain access to credit from microcredit organizations to start their own businesses, facilitated through the partnership
- Microcredit clients who receive loans from WS&S providers are already familiar with credit and savings mechanisms; as such, they are more responsible and a better credit risk than the general population
- Micro-entrepreneurs will be healthier and more productive borrowers, once they have access to basic WS&S services.¹⁰⁴

The next step: going to scale

The 1997 Microcredit Summit was the first step in a nine-year campaign to reach 100 million of the world's poorest families with credit and other financial services by 2005. Going to scale in microcredit will require escalating from the current numbers reached, approximately 20 million borrowers, to the goal of the Summit, 100 million families, in less than 9 years. According to Muhammad Yunus, the founder of the Grameen Bank, if the Grameen Bank has alone been able to reach 2.1 million

borrowers in Bangladesh in the course of a decade, who is to say the remaining microcredit borrowers cannot be reached by the year 2005?

At a minimum, the same declaration of reaching 100 million of the world's poorest families also must be met within the WS&S sector. Invariably, a disproportionate share of those same 100 million families targeted by the microcredit movement — because they are extremely poor — do not have adequate access to basic WS&S services. In addition, many of these poor who migrate to the cities from rural areas in search of jobs and opportunity eventually end up settling with the rest of the most vulnerable populations in the world, within the peri-urban regions.

Clearly, the methods will vary from country to country, from region to region, and even from village to village. But the goal remains the same: targeted efforts to reach the peri-urban poor with basic WS&S services that are sustainable — from an economic, health and environmental standpoint. By maximizing coordination between the global microcredit movement and the WS&S sector, the groundwork will be laid to reach as many of those 100 million families as is possible, enabling the beneficiaries to have improved incomes while leading healthier and more productive lives.

Working with the microcredit community, the WS&S sector will be able to meet the needs of more people. And in reaching the 100 million families targeted by the microcredit community with water and sanitation, they will not have to worry about where their next clean glass of water is coming from or whether they will have to worry about health hazards associated with inadequate sanitation. In summary, we must build on the health-development link, keeping the following provisions in mind:

- The microcredit movement must clearly recognize microcredit as a means of improving the health status and quality of life of the poorest people and the disadvantaged. Extending the provision of basic services conducive to health such as WS&S should be targeted in addition to raising income

- Those involved with microcredit must adopt concrete measures to link economic and health objectives in lending operations for vulnerable people (such as those being proposed in this paper, with respect to WS&S provision for the peri-urban poor).¹⁰⁵

The microcredit/WS&S partnership can gain much insight from the Grameen model, with respect to going to scale. By working closely with the expanding microcredit community in a pilot community, WS&S providers can conceivably reach a scale proportional to that of the Grameen model in Bangladesh with basic peri-urban WS&S provision. If a microcredit/WS&S partnership were successful, there is ample reason to believe that further partnerships could be extended to other viable microcredit institutions that currently operate in peri-urban communities.

A microcredit/WS&S partnership through a demonstration project, and subsequently through a national program, can provide a solid foundation for an eventual plan to expand WS&S services to the peri-urban poor, as well as rural and marginal communities, on a regional level. If the regional model proves successful, it could then be tried out in other parts of the world. The ultimate goal would be to reach scale, by offering WS&S services to microcredit recipients all over the world.

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