

# THE HUMANURE HANDBOOK

THIRD EDITION  
A GUIDE TO COMPOSTING HUMAN MANURE

by Joseph Jenkins

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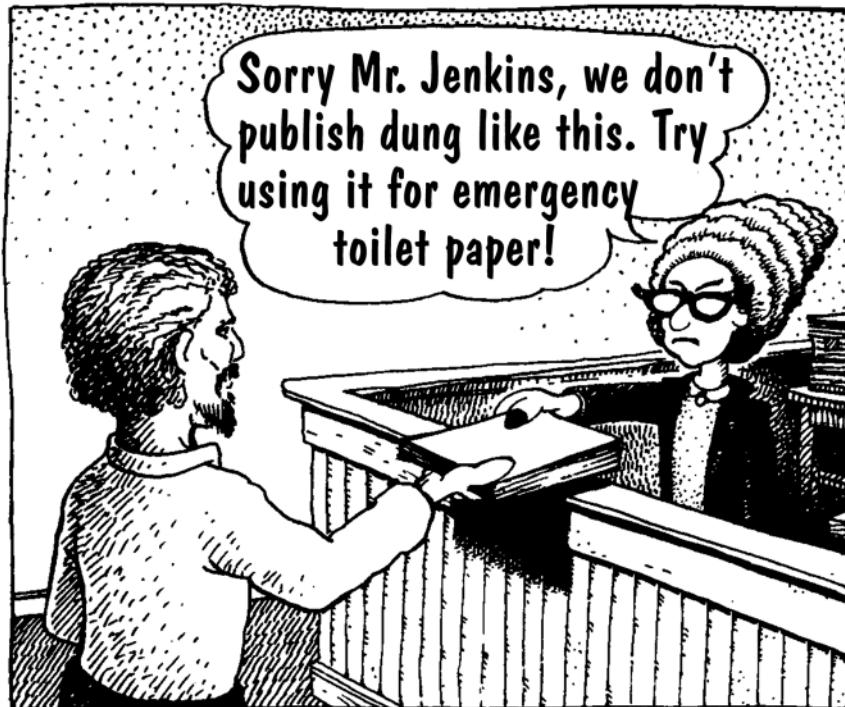
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This is the third edition of a self-published book. No respectable publisher would touch it with a ten foot shovel. Nevertheless, the book has now been sold in at least 57 countries worldwide and has been published in foreign editions on four continents. It has been talked about on NPR, BBC, CBC, Howard Stern, in The Wall Street Journal, Playboy Magazine and many other national and international venues. For more information about this and the author's other books, visit the publisher's website at:

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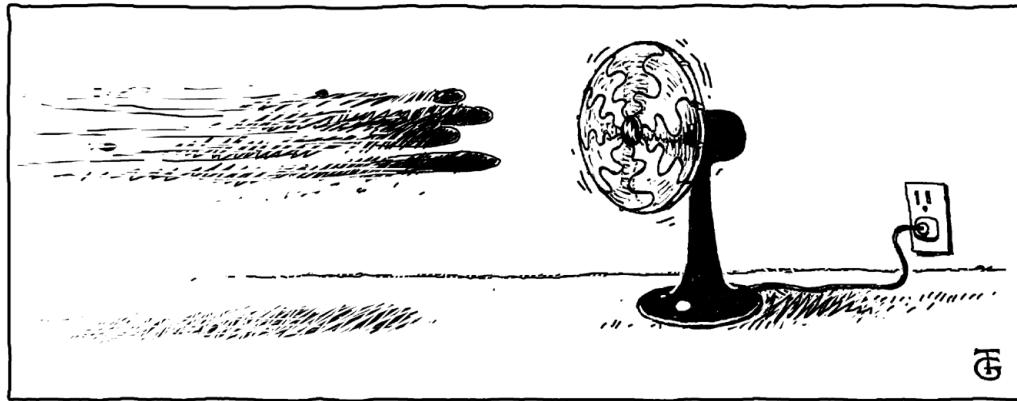


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*The Humanure Handbook - Third Edition*

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## CRAP HAPPENS

### Something's About to Hit the Fan

*"Human beings and the natural world are on a collision course . . . No more than one or a few decades remain before the chance to avert the threats we now confront will be lost and the prospects for humanity immeasurably diminished."*

1,600 Senior Scientists, November 18, 1992 — World Scientists Warning to Humanity

**T**here is a disturbing theory about the human species that has begun to take on an alarming level of reality. It seems that the behavior of the human race is displaying uncanny parallels to the behavior of pathogenic, or disease-causing, organisms.

When viewed at the next quantum level of perspective, from which the Earth is seen as an organism and humans are seen as microorganisms, the human species looks like a menace to the planet. In fact, the human race is looking a lot like a disease — comprised of organisms excessively multiplying, mindlessly consuming, and generating waste with little regard for the health and well-being of its host — planet Earth.

Pathogenic organisms are a nasty quirk of nature, although they do have their constructive purposes, namely killing off the weak and infirm and ensuring the survival only of the fittest. They do this by overwhelming their host, by sucking the vitality out of it and leaving poison in their wake. Pathogens don't give a damn about their own source of life — their host — and they often kill it outright.

This may seem like a silly way for a species to maintain its own existence; afterall, if you kill the host upon which your life depends, then you must also die. But pathogens have developed a special survival tactic that allows them to carry on their existence even

after their host has died. They simply travel to a new host, sending out envoys to seek out and infect another organism even as their own population dies en masse along with the original host.

A man dying of tuberculosis coughs on his deathbed, an act instigated by the infecting pathogen, ensuring that the disease has a chance to spread to others. A child defecates on the dirt outside her home, unwittingly satisfying the needs of the parasites inhabiting her intestines, which require time in the soil as part of their life cycle. A person stricken with cholera defecates in an outhouse which leaches tainted water into the ground, contaminating the village well-water and allowing the disease to spread to other unsuspecting villagers.

In the case of pathogenic organisms that kill their host, the behavior is predictable: multiply without regard for any limits to growth, consume senselessly and excrete levels of waste that grievously harm the host. When this is translated into human terms, it rings with a disquieting familiarity, especially when we equate human success with growth, consumption and material wealth.

Suppose we humans are, as a species, exhibiting disease behavior: we're multiplying with no regard for limits, consuming natural resources as if there will be no future generations, and producing waste products that are distressing the planet upon which our very survival depends. There are two factors which we, as a species, are not taking into consideration. First is the survival tactic of pathogens, which requires additional hosts to infect. We do not have the luxury of that option, at least not yet. If we are successful at continuing our dangerous behavior, then we will also succeed in marching straight toward our own demise. In the process, we can also drag many other species down with us, a dreadful syndrome that is already underway. This is evident by the threat of extinction that hangs, like the sword of Damocles, over an alarming number of the Earth's species.

There is a second consideration: infected host organisms fight back. As humans become an increasing menace, can the Earth try to defend itself? When a disease organism infects a human, the human body elevates its own temperature in order to defend itself. This rise in temperature not only inhibits the growth of the infecting pathogen, but also greatly enhances the disease fighting capability within the body. Global warming may be the Earth's way of inducing a global "fever" as a reaction to human pollution of the atmosphere and human over-consumption of fossil fuels.

When the internal human body temperature rises, the micro-

climate of the body changes, allowing for the sudden and rapid proliferation of antibodies, T-cells, white blood cells and other defenders against disease. As the *Earth's* climate changes and as the natural environment chokes with pollution, we humans already have an idea of what sort of organisms nature can and will suddenly unleash to confront us. They're beginning to show themselves as insect pests and new strains of deadly bacteria, viruses and algae particularly toxic to humans.

As the planet's temperature rises, it gains a momentum that cannot be stopped or even stalled, no matter how desperate or repentant we humans may eventually become. The Earth's "fever," like a spinning flywheel, will only subside in *its* own time. We may be creating a Frankenstein's monster of astronomical proportions, unless, of course, we *are* pathogenic organisms. If so, then we really don't care, do we?

Pathogens can often dwell for quite some time within the host organism without causing disease symptoms. Then something happens to spark their growth — they gain a sudden foothold and begin proliferating rapidly. It is at this point that undeniable disease effects begin to show themselves.

Humans began to show their pathogenic potential toward the planet during the 1950s, ravenously devouring natural resources and discarding waste into the environment with utter carelessness. From 1990 to 1997, human global consumption grew as much as it did from the beginning of civilization until 1950. In fact, the global economy grew more in 1997 alone than during the entire 17th century.<sup>1</sup>

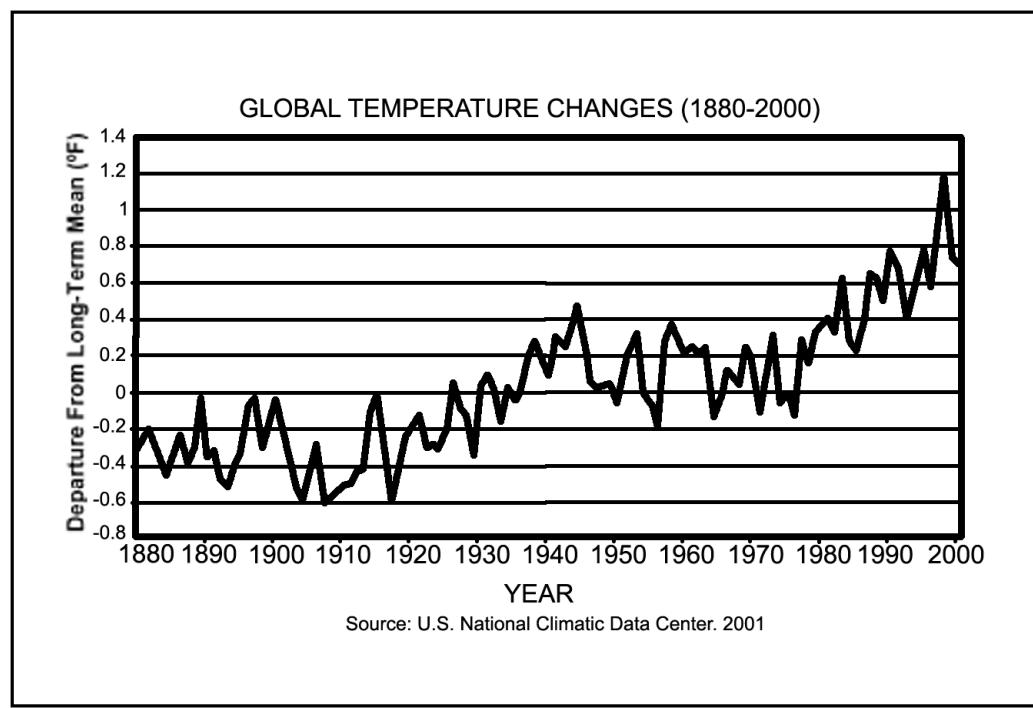
By the end of the 20th century, our consumptive and wasteful lifestyles had painted a bleak global picture. Almost half of the world's forests are gone. Between 1980 and 1995, we lost areas of forest larger than the size of Mexico, and we're still losing forests at a rate of millions of acres a year.<sup>2</sup> Water tables are falling on every continent. Fisheries are collapsing, farmland is eroding, rivers are drying, wetlands are disappearing and species are becoming extinct.<sup>3</sup> Furthermore, the human population is now increasing by 80 million each year (roughly the population of ten Swedens). Population growth without foresight, management and respect for the environment virtually guarantees increased consumption and waste with each passing year.<sup>4</sup>

The natural background rate of extinctions is estimated to be about one to ten species per year. Currently, it's estimated that we're instead losing 1,000 species per year. More than 10% of all bird

species, 25% of all mammals, and 50% of all primates are threatened with extinction.<sup>5</sup> Of 242,000 plant species surveyed by the World Conservation Union in 1997, one out of every eight (33,000 species) was threatened with extinction.<sup>6</sup>

What would drive humanity to damage its life support system in this way? Why would we disregard our host organism, the Earth, as if we were nothing more than a disease intent upon its destruction? One answer, as we have seen, is consumption. We embrace the idea that more is better, measuring success with the yardstick of material wealth. Some startling statistics bear this out: the 225 richest people in the world (0.000003% of the world's population) have as much acquired wealth as the poorest *half* of the entire human race. The wealth of the world's three richest people is equivalent to the total output of the poorest 48 countries. We in the United States certainly can raise our hands and be counted when it comes to consumption — our intake of energy, grain and materials is the highest on the planet. Americans can admit to using three tons of materials per month, each of us, and that's not counting food and fuel. Despite the fact that we are only 1/20th of the globe's population, we use 1/3 of its resources. We would require no less than three planet Earths to sustain the entire world at this level of consumption.<sup>7</sup>

There are those who scoff at the idea that a tiny organism such as the human species could mortally affect such an ancient and immense being as Mother Earth. The notion that we can be powerful



# Pathogen Alert!

- Although the natural background rate of extinctions is estimated to be about one to ten species per year, we are currently losing 1,000 species per year.
- Since the 1950s, more than 750 million tons of toxic chemical wastes have been dumped into the environment.<sup>16</sup>
- By the end of the 1980s, production of human-made synthetic organic chemicals linked to cancer had exceeded 200 billion pounds per year, a hundred-fold increase in only two generations.<sup>17</sup>
- By 1992, in the U.S. alone, over 435 billion pounds of carbon-based synthetic chemicals were being produced.<sup>18</sup>
- In 1994, well over a million tons of toxic chemicals were released into the environment. Of these, 177 million pounds were known or suspected carcinogens.<sup>19</sup>
- There are now about 75,000 chemicals in commercial use, and 3,750 to 7,500 are estimated to be cancer-causing to humans.
- There are 1,231 “priority” Superfund sites, with 40 million people (one in every six Americans) living within four miles of one.<sup>20</sup>
- 40% of Americans can expect to contract cancer in their lifetimes.
- 80% of all cancer is attributed to environmental influences.
- Breast cancer rates are thirty times higher in the United States than in parts of Africa.
- Childhood cancers have risen by one third since 1950 and now one in every four hundred Americans can expect to develop cancer before the age of fifteen.
- The U.S. EPA projects that tens of thousands of additional fatal skin cancers will result from the ozone depletion that has already occurred over North America.<sup>21</sup>
- Male fish are being found with female egg sacs, male alligators with shriveled penises, and human male sperm counts are plummeting.
- The average person can now expect to find at least 250 chemical contaminants in his or her body fat.<sup>22</sup>
- Fifty new diseases have emerged since 1950, including Ebola, Lyme’s Disease, Hantavirus, and HIV.<sup>23</sup>
- Earth’s atmospheric concentrations of CO<sub>2</sub> have climbed to the highest level in 150,000 years.

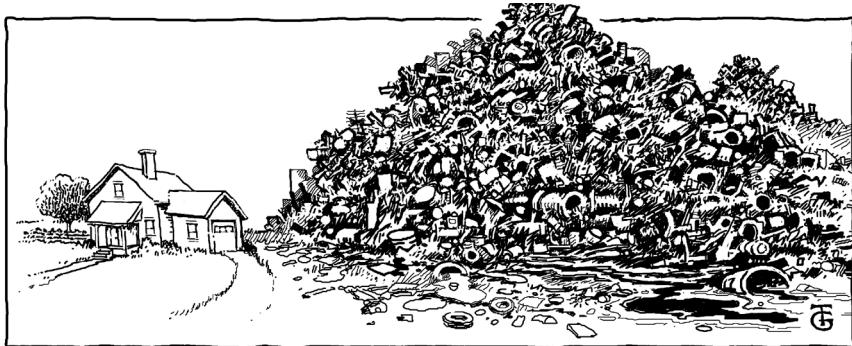


enough to inflict illness on a planetary being is nothing more than egotism. Where is there any evidence that a planet can get sick and die? Well, how about Mars?

What did happen to Mars, anyway? Our next door neighbor, the Red Planet, apparently was once covered with flowing rivers. What happened to them? Rivers suggest an atmosphere. Where is it? Was Mars once a vital, thriving planet? If so, why does it now appear dead? Could a lifeform on its surface have proliferated so abundantly and so recklessly that it altered the planet's atmosphere, thereby knocking it off-kilter and destroying it? Is that what's happening to our own planet? Will it be our legacy in this solar system to leave behind another lonely, dead rock to revolve around the sun? Or will we simply destroy ourselves while the Earth, stronger than her Martian brother, overcomes our influence and survives to flourish another billion years — without us?

The answer, if I may wildly speculate, is neither — we will destroy neither the Earth nor ourselves. Instead, we will learn to live in a symbiotic relationship with our planet. To put it simply, the human species has reached a fork in the road of its evolution. We can continue to follow the way of disease-causing pathogens, or we can chart a new course as dependent and respectful inhabitants on this galactic speck of dust we call Earth. The former requires only an ego-centric lack of concern for anything but ourselves, living as if there will be no future human generations. The latter, on the other hand, requires an awareness of ourselves as a dependent part of a Greater Being. This may require a hefty dose of humility, which we can either muster up ourselves, or wait until it's meted out to us, however tragically, by the greater world around us. Either way, time is running out.

It is ironic that humans have ignored one waste issue that all of us contribute to each and every day — an environmental problem that has stalked our species from our genesis, and which will accompany us to our extinction. Perhaps one reason we have taken such a head-in-the-sand approach to the recycling of human excrement is because we can't even talk about it. If there is one thing that the human consumer culture refuses to deal with maturely and constructively, it's bodily excretions. This is the taboo topic, the unthinkable issue. It's also the one we are about to dive headlong into. For waste is not found in nature — except in human nature. It's up to us humans to unlock the secret to its elimination. Nature herself provides a key and she has held it out to us for eons.



## WASTE NOT WANT NOT

*“WASTE: . . . Spoil or destruction, done or permitted, to lands, houses, gardens, trees, or other corporeal hereditaments, by the tenant thereof . . . Any unlawful act or omission of duty on the part of the tenant which results in permanent injury to the inheritance . . .”* Black’s Law Dictionary

**A**merica is not only a land of industry and commerce, it's also a land of consumption and waste, producing between 12 and 14 billion tons of waste annually. Much of our waste consists of organic material including food residues, municipal leaves, yard materials, agricultural residues, and human and livestock manures, all of which should be returned to the soil from which they originated. These organic materials are very valuable agriculturally, a fact well known among organic gardeners and farmers.

Feces and urine are examples of natural, beneficial, organic materials excreted by the bodies of animals after completing their digestive processes. They are only “waste” when we discard them. When recycled, they are resources, and are often referred to as manures, but never as *waste*, by the people who do the recycling.

We do not *recycle waste*. It's a common semantic error to say that waste is, can be, or should be recycled. Resource materials are recycled, but waste is never recycled. That's why it's called “waste.” Waste is any material that is discarded and has no further use. We humans have been so wasteful for so long that the concept of waste

*elimination* is foreign to us. Yet, it is an important concept.

When a potato is peeled, the peels aren't kitchen waste — they're still potato peels. When they're collected for composting, they are being recycled and no waste is produced.

Composting professionals sometimes refer to recycled materials as "waste." Many of the people who are developing municipal composting programs came from the waste management field, a field in which refuse has always been termed "waste." Today, however, the use of the term "waste" to describe recycled materials is an unpleasant semantic habit that must be abandoned. Otherwise, one could refer to leaves in the autumn as "tree waste," because they are no longer needed by the tree and are discarded. Yet, when one walks into the forest, where does one see waste? The answer is "nowhere," because the forest's organic material is recycled naturally, and no waste is created. Ironically, leaves and grass clippings are referred to as "yard waste" by some compost professionals, another example of the persistent waste mentality plaguing our culture.

One organism's excrement is another's food. Everything is recycled in natural systems, thereby eliminating waste. Humans create waste because we insist on ignoring the natural systems upon which we depend. We are so adept at doing so that we take waste for granted and have given the word a prominent place in our vocabulary. We have kitchen "waste," garden "waste," agricultural "waste," human "waste," municipal "waste," "biowaste," and on and on. Yet, our long-term survival requires us to learn to live in harmony with our host planet. This also requires that we understand natural cycles and incorporate them into our day to day lives. In essence, this means that we humans must attempt to eliminate waste altogether. As we progressively eliminate waste from our living habits, we can also progressively eliminate the word "waste" from our vocabulary.

"Human waste" is a term that has traditionally been used to refer to human excrements, particularly fecal material and urine, which are by-products of the human digestive system. When *discarded*, as they usually are, these materials are colloquially known as human *waste*, but when *recycled* for agricultural purposes, they're known by various names, including *night soil* when applied raw to fields in Asia.

*Humanure*, unlike *human waste*, is not waste at all — it is an organic resource material rich in soil nutrients. Humanure originated from the soil and can be quite readily returned to the soil, especially if converted to humus through the composting process.

Human waste (*discarded* feces and urine), on the other hand, creates significant environmental problems, provides a route of transmission for disease, and deprives humanity of valuable soil fertility. It's also one of the primary ingredients in sewage, and is largely responsible for much of the world's water pollution.

A clear distinction must be drawn between humanure and sewage because they are two very different things. Sewage can include waste from many sources — industries, hospitals and garages, for example. Sewage can also contain a host of contaminants such as industrial chemicals, heavy metals, oil and grease, among others. Humanure, on the other hand, is strictly human fecal material and urine.

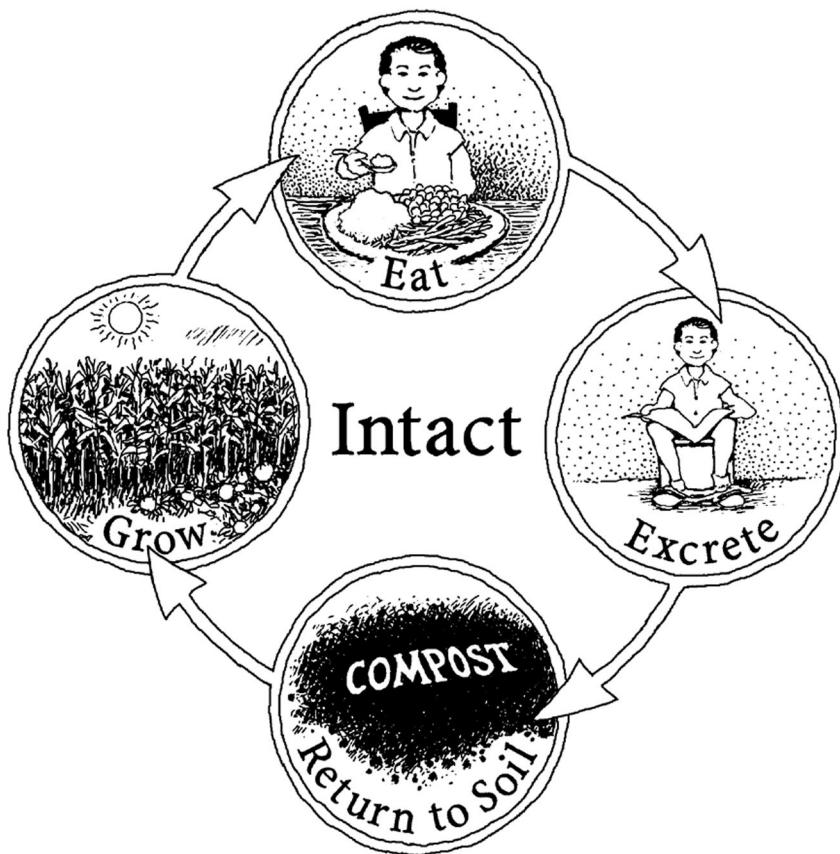
What, in truth, *is* human waste? Human waste is garbage, cigarette butts, plastic six-pack rings, styrofoam clamshell burger boxes, deodorant cans, disposable diapers, worn out appliances, unrecycled pop bottles, wasted newspapers, junk car tires, spent batteries, junk mail, nuclear contamination, food packaging, shrink wrap, toxic chemical dumps, exhaust emissions, discarded plastic CD disks, the five billion gallons of drinking water we flush down our toilets every day, and the millions of tons of organic material discarded into the environment year after year after year.

## THE HUMAN NUTRIENT CYCLE

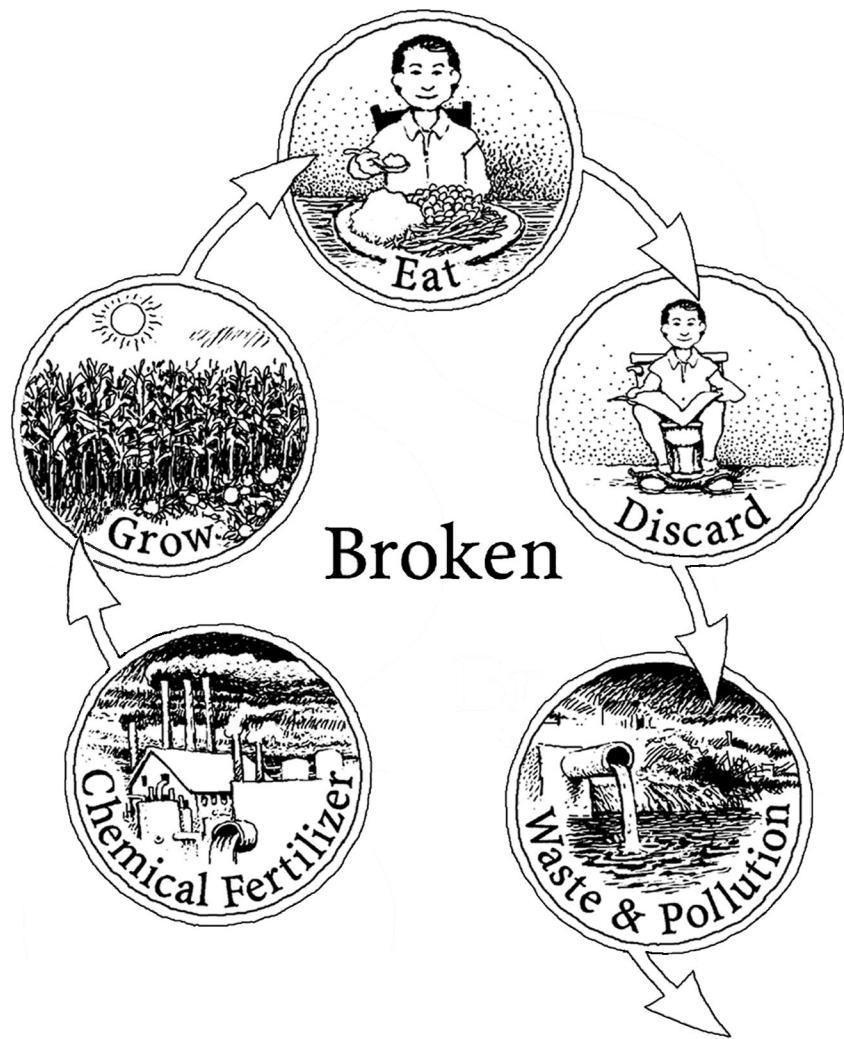
When crops are produced from soil, it is advisable that the organic residues resulting from those crops, including animal excrements, be returned to the soil from which the crops originated. This recycling of organic residues for agricultural purposes is fundamental to sustainable agriculture. Yet, spokespersons for sustainable agriculture movements remain silent about using humanure for agricultural purposes. Why?

Perhaps the silence is because there is currently a profound lack of knowledge and understanding about what is referred to as the "human nutrient cycle" and the need to keep the cycle intact. The human nutrient cycle goes like this: a) we grow food, b) we eat it, c) we collect and process the organic residues (feces, urine, food scraps and agricultural materials) and d) we then return the processed organic material back to the soil, thereby enriching the soil and enabling more food to be grown. This cycle can be repeated, endlessly. This is a process that mimics the cycles of nature and enhances our ability to survive on this planet. When our food refuse materials are

# The *HUMAN* NUTRIENT CYCLE



The Human Nutrient Cycle is an endless natural cycle. In order to keep the cycle intact, food for humans must be grown on soil that is enriched by the continuous addition of organic materials recycled by humans, such as humanure, food scraps and agricultural residues. By respecting this cycle of nature, humans can maintain the fertility of their agricultural soils indefinitely, instead of depleting them of nutrients, as is common today.



Food-producing soils must be left more fertile after each harvest due to the ever-increasing human population and the need to produce more food with each passing year.

instead discarded as waste, the natural human nutrient cycle is broken, creating problems such as pollution, loss of soil fertility and abuse of our water resources.

We in the United States each waste about a thousand pounds of humanure every year, which is discarded into sewers and septic systems throughout the land. Much of the discarded humanure finds its final resting place in a landfill, along with the other solid waste we Americans discard, which, coincidentally, also amounts to about a thousand pounds per person per year. For a population of 290 million people, that adds up to nearly 290 million tons of solid waste personally discarded by us every year, at least half of which would be valuable as an agricultural resource.

The practice we humans have frequently employed for waste disposal has been quite primitive — we dump our garbage into holes in the ground, then bury it. That's now called a landfill, and for many years they were that simple. Today's new "sanitary" landfills are lined with waterproof, synthetic materials to prevent the leaching of garbage juice into groundwater supplies. Yet, only about a third of the active dumps in the U.S. have these liners.<sup>1</sup> Interestingly, the lined landfills bear an uncanny resemblance to gigantic disposable diapers. They're gargantuan plastic-lined receptacles where we lay our crap to rest, the layers being carefully folded over and the end products of our wasteful lifestyles buried as if they were in garbage mausoleums intended to preserve our sludge and kitchen trash for posterity. We conveniently flush our toilets, and the resultant sewage sludge is transported to these landfills, tucked into these huge disposable diapers and buried.

This is not to suggest that *sewage* should be used to produce food crops. Sewage consists of humanure collected with hazardous materials such as industrial, medical and chemical wastes, all carried in a common waterborne waste stream. Or in the words of Gary Gardner (State of the World 1998), "*Tens of thousands of toxic substances and chemical compounds used in industrial economies, including PCBs, pesticides, dioxins, heavy metals, asbestos, petroleum products, and industrial solvents, are potentially part of sewage flows.*" Not to mention pathogenic organisms. When raw sewage was used agriculturally in Berlin in 1949, for example, it was blamed for the spread of worm-related diseases. In the 1980s, it was said to be the cause of typhoid fever in Santiago, and in 1970 and 1991 it was blamed for cholera outbreaks in Jerusalem and South America, respectively.<sup>2</sup>

Humanure, on the other hand, when kept out of the sewers,

collected as a resource material, and properly composted, makes a suitable agricultural resource for food crops. When we combine our manure with other organic materials such as food and farming byproducts, we can achieve a blend that is irresistible to certain beneficial microorganisms.

The U.S. EPA estimates that nearly 22 million tons of food waste are produced in American cities every year. Throughout the United States, food losses at the retail, consumer and food services levels are estimated to have been 48 million tons in 1995.<sup>3</sup> That would make great organic material for composting with humanure. Instead, only a small percentage of our discarded food is being composted in the U.S.; the remaining is incinerated or buried in landfills.<sup>4</sup>

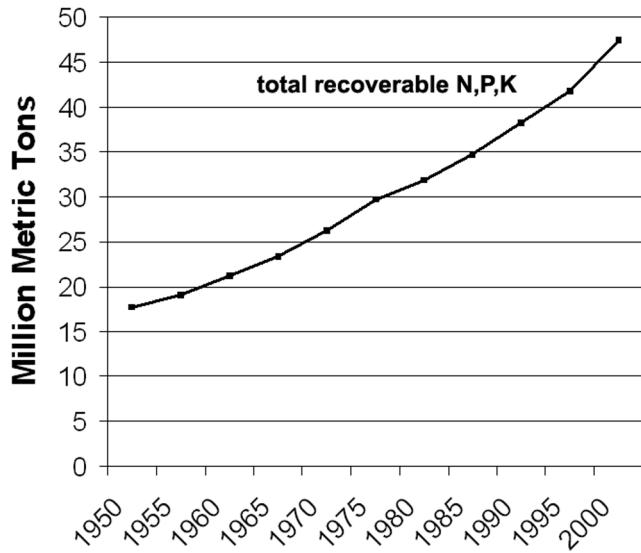
The Organization for Economic Cooperation and Development, a group made up primarily of western industrial countries, estimates that 36% of the waste in their member states is organic food and garden materials. If paper is also considered, the organic share of the waste stream is boosted to nearly an incredible two thirds! In developing countries, organic material typically makes up one half to two thirds of the waste stream.<sup>5</sup> According to the EPA, almost 80% of the net discarded solid waste in the U.S. is composed of organic material.

It is becoming more and more obvious that it is unwise to rely on landfills to dispose of recyclable materials. Landfills overflow and new ones need to be built to replace them. In fact, we may be lucky that landfills are closing so rapidly — they are notorious polluters of water, soil, and air. Of the ten thousand landfills that have closed since 1982, 20% are now listed as hazardously contaminated Superfund sites. A 1996 report from the state of Florida revealed that groundwater contamination plumes from older, unlined landfills can be longer than 3.4 miles, and that 523 public water supplies in Florida are located within one mile of these closed landfills, while 2,700 lie within three miles.<sup>6</sup> No doubt similar situations exist throughout the United States.

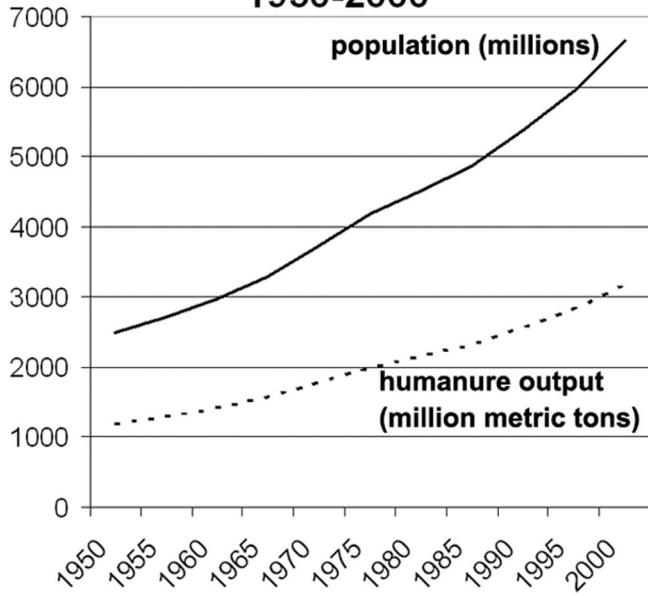
Organic material disposed of in landfills also creates large quantities of methane, a major global-warming gas. U.S. landfills are “*among the single greatest contributors of global methane emissions,*” according to the Natural Resources Defense Council. According to the EPA, methane is 20 to 30 times more potent than CO<sub>2</sub> as a greenhouse (global warming) gas on a molecule to molecule basis.<sup>7</sup>

Tipping fees (the fee one pays to dump waste) at landfills in every region of the U.S. have been increasing at more than twice the

### AGRONUTRIENTS RECOVERABLE FROM HUMANURE WORLDWIDE



### Global Humanure Production 1950-2000



Source: Fahm, Lattee A., (1980), *The Waste of Nations*; pp. 33 and 38;  
Allanheld, Osmun and Co. Publishers, Inc., Montclair, NJ USA.

rate of inflation since 1986. In fact, since then, they have increased 300% and are expected to continue rising at this rate.<sup>8</sup>

In developing countries, the landfill picture is also bleak. In Brazil, for example, 99% of the solid waste is dumped into landfills and three fourths of the 90,000 tons per day ends up in open dumps.<sup>9</sup> Slowly we're catching on to the fact that this throw-away trend has to be turned around. We can't continue to throw "away" usable resources in a wasteful fashion by burying them in disappearing, polluting, increasingly expensive landfills.

If we had scraped up all the human excrement in the world and piled it on the world's tillable land in 1950, we'd have applied nearly 200 metric tons per square mile at that time (roughly 690 pounds per acre). In the year 2000, we would have been collecting more than *double* that amount because the global population is increasing, but the global land mass isn't. In fact, the global area of agricultural land is steadily *decreasing* as the world loses, for farming and grazing, an area the size of Kansas each year.<sup>10</sup> The world's burgeoning human population is producing a ballooning amount of organic refuse which will eventually have to be dealt with responsibly and constructively. It's not too soon to begin to understand human organic refuse as valuable resources begging to be recycled.

In 1950, the dollar value of the agricultural nutrients in the world's gargantuan pile of humanure was 6.93 billion dollars. In 2000, it would have been worth 18.67 billion dollars calculated in 1975 prices.<sup>11</sup> This is money currently being flushed out somewhere into the environment where it shows up as pollution and landfill material. Every pipeline has an outlet somewhere; everything thrown "away" just moves from one place to another. Humanure and other organic refuse materials are no exception. Not only are we flushing "money" away, we're paying to do so. The cost is not only economic, it's environmental.

#### SOILED WATER

The world is divided into two categories of people: those who shit in their drinking water supplies and those who don't. We in the western world are in the former class. We defecate into water, usually purified drinking water. After polluting the water with our excrements, we flush the polluted water "away," meaning we probably don't know where it goes, nor do we care.

Every time we flush a toilet, we launch five or six gallons of polluted water out into the world.<sup>12</sup> That would be like defecating into

## FUN FACTS *about water*

- If all the world's drinking water were put in one cubical tank, the tank would measure only 95 miles on each side.
- People currently lacking access to clean drinking water: 1.2 billion.
- % of world's households that must fetch water outside their homes: 67
- % increase in the world's population by mid 21st century: 100
- % increase in the world's drinking water supplies by mid 21st century: 0
- Amount of water Americans use every day: 340 billion gallons.
- Number of gallons of water needed to produce a car: 100,000
- Number of cars produced every year: 50 million.
- Amount of water annually required by a nuclear reactor: 1.9 cubic miles.
- Amount of water used by nuclear reactors every year: the equivalent of one and a third Lake Eries.

Sources: Der Spiegel, May 25, 1992; and Annals of Earth, Vol. 8, Number 2, 1990; Ocean Arks International, One Locust Street, Falmouth, MA 02540.



## WATER, WATER EVERYWHERE

### AND IT'S ALL GOING DOWNHILL

- In the mid 1980s, the 2,207 publicly owned coastal sewage treatment works were discharging 3.619 trillion gallons per year of treated wastewater into the coastal environment.<sup>14</sup>
- In 1997, pollution caused at least 4,153 beach closings and advisories, 69% of which were caused by elevated bacterial pollution in the water.<sup>15</sup>
- In 2001, of the 2,445 beaches surveyed by the EPA, 672 were affected by advisories or closings, most often due to elevated bacteria levels.
- In 2003, there were more than 18,000 days of pollution-related closings and advisories at U.S. beaches according to NRDC's annual report on beachwater quality. 88% of the closings and advisories stemmed from the presence of bacteria associated with fecal contamination.
- According to the U.S. Environmental Protection Agency, the primary cause reported for beach closings is the overflow of combined storm-water and sewage systems with insufficient capacity to retain heavy rains for processing through sewage treatment plants.
- In 2002, New York State sued Yonkers over sewage discharges, alleging that thousands of gallons per day of untreated sewage were discharged into the Bronx River from at least four pipes owned and operated by the city. Laboratory results showed that the pollution contained the bacteria *fecal coliform*, an indicator of raw sewage, in concentrations as high as 250 times more than allowed by New York State water quality standards.
- In 2002, a federal judge found Los Angeles liable for 297 sewage spills. From 1993 to January, 2002, the city reported 3,000 sewage spills. Los Angeles has about 6,500 miles of sewers. The spills end up in waterways, are carried into the ocean and pollute beaches.<sup>16</sup>
- United Nations Environment Program (UNEP) studies show that over 800 million people in coastal South Asia have no basic sanitation services, putting them at high risk from sewage-related diseases and death.
- In 2000, 55% of U.S. lakes, rivers and estuaries were not clean enough for fishing or swimming according to EPA testimony before Congress in 2002. In 1995, 40% were too polluted to allow fishing, swimming or other aquatic uses at any time of the year, according to the United States Environmental Protection Agency.
- In January of 2005 it was reported that twenty-two percent of U.S. coastal waters were unsuitable for fishing, based on EPA guidelines for moderate consumption of recreationally-caught fish.

a five gallon office water jug and then dumping it out before anyone could drink any of it. Then doing the same thing when urinating. Then doing it every day, numerous times. Then multiplying that by about 290 million people in the United States alone.

Even after the contaminated water is treated in wastewater treatment plants, it may still be polluted with excessive levels of nitrates, chlorine, pharmaceutical drugs, industrial chemicals, detergents and other pollutants. This “treated” water is discharged directly into the environment.

It is estimated that by 2010, at least half of the people in the U.S. will live in coastal cities and towns, further exacerbating water pollution problems caused by sewage. The degree of beach pollution becomes a bit more personal when one realizes that current EPA recreational water cleanliness standards still allow 19 illnesses per 1,000 saltwater swimmers, and 8 per 1,000 freshwater swimmers.<sup>13</sup> Some of the diseases associated with swimming in wastewater-contaminated recreational waters include typhoid fever, salmonellosis, shigellosis, hepatitis, gastroenteritis, pneumonia, and skin infections.<sup>17</sup>

If you don’t want to get sick from the water you swim in, don’t submerge your head. Otherwise, you may end up like the swimmers in Santa Monica Bay. People who swam in the ocean there within 400 yards (four football fields) of a storm sewer drain had a 66% greater chance of developing a “significant respiratory disease” within the following 9 to 14 days after swimming.<sup>18</sup>

This should come as no surprise when one takes into consideration the emergence of antibiotic-resistant bacteria. The use of antibiotics is so widespread that many people are now breeding antibiotic resistant bacteria in their intestinal systems. These bacteria are excreted into toilets and make their way to wastewater treatment plants where *the antibiotic resistance can be transferred to other bacteria*. Wastewater plants can then become breeding grounds for resistant bacteria, which are discharged into the environment through effluent drains. Why not just chlorinate the water before discharging it? It usually *is* chlorinated beforehand, but research has shown that chlorine seems to *increase* bacterial resistance to some antibiotics.<sup>19</sup>

Not worried about antibiotic-resistant bacteria in your swimming area? Here’s something else to chew on: 50 to 90% of the pharmaceutical drugs people ingest can be excreted down the toilet and out into the waterways *in their original or biologically active forms*. Furthermore, drugs that have been partially degraded before excre-

tion can be converted to their original active form by environmental chemical reactions. Pharmaceutical drugs such as chemotherapy drugs, antibiotics, antiseptics, beta-blocker heart drugs, hormones, analgesics, cholesterol-lowering drugs and drugs for regulating blood lipids have turned up in such places as tap water, groundwater beneath sewage treatment plants, lake water, rivers and in drinking water aquifers. Think about *that* the next time you fill your glass with water.<sup>20</sup>

Long Island Sound receives over a billion gallons of treated sewage every day — the waste of eight million people. So much nitrogen was being discharged into the Sound from the *treated* wastewater that it caused the aquatic oxygen to disappear, rendering the marine environment unsuitable for the fish that normally live there. The twelve treatment plants that were to be completed along the Sound by 1996 were expected to remove 5,000 pounds of nitrogen daily. Nitrogen is normally a soil nutrient and agricultural resource, but instead, when flushed, it becomes a dangerous water pollutant.<sup>21</sup> On December 31, 1991, the disposal of U.S. sewage sludge into the ocean was banned. Before that, much of the sewage sludge along coastal cities in the United States had simply been dumped out to sea.

The discharging of sludge, sewage, or wastewater into nature's waterways invariably creates pollution. The impacts of polluted water are far-ranging, causing the deaths of 25 million people each year, three-fifths of them children.<sup>22</sup> Half of all people in developing countries suffer from diseases associated with poor water supply and sanitation.<sup>23</sup> Diarrhea, a disease associated with polluted water, kills six million children each year in developing countries, and it contributes to the deaths of up to 18 million people.<sup>24</sup> At the beginning of the 21st century, one out of four people in developing countries still lacked clean water, and two out of three lacked adequate sanitation.<sup>25</sup>

Proper sanitation is defined by the World Health Organization as any excreta *disposal* facility that interrupts the transmission of fecal contaminants to humans.<sup>26</sup> This definition should be expanded to include excreta *recycling* facilities. Compost toilet systems are now becoming internationally recognized as constituting “proper sanitation,” and are becoming more and more attractive throughout the world due to their relatively low cost when compared to waterborne waste systems and centralized sewers. In fact, compost toilet systems yield a dividend — *humus*, which allows such a sanitation system to yield a net profit, rather than being a constant finan-

cial drain (no pun intended). The obsession with flush toilets throughout the world is causing the problems of international sanitation to remain unresolved. Many parts of the world cannot afford expensive and water consumptive waste disposal systems.

We're also depleting our water supplies, and flushing toilets is one way it's being wasted. Of 143 countries ranked for per capita water usage by the World Resources Institute, America came in at #2 using *188 gallons per person per day* (Bahrain was #1).<sup>27</sup> Water use in the U.S. increased by a factor of 10 between 1900 and 1990, increasing from 40 billion gallons per day to 409 billion gallons per day.<sup>28</sup> The amount of water we Americans require overall, used in the finished products each of us consumes, plus washing and drinking water, amounts to a staggering 1,565 gallons per person per day, which is three times the rate of Germany or France.<sup>29</sup> This amount of water is equivalent to flushing our toilets 313 times every day, about once every minute and a half for eight hours straight. By some estimates, it takes one to two thousand tons of water to flush one ton of human waste.<sup>30</sup> Not surprisingly, the use of groundwater in the United States exceeds replacement rates by 21 billion gallons a day.<sup>31</sup>

## WASTE VS. MANURE

By dumping soil nutrients down the toilet, we increase our need for synthetic chemical fertilizers. Today, pollution from agriculture, caused from siltation (erosion) and nutrient runoff due to excessive or incorrect use of fertilizers,<sup>32</sup> is now the "*largest diffuse source of water pollution*" in our rivers, lakes, and streams.<sup>33</sup> Chemical fertilizers provide a quick fix of nitrogen, phosphorous and potassium for impoverished soils. However, it's estimated that 25-85% of chemical nitrogen applied to soil and 15-20% of the phosphorous and potassium are lost to leaching, which pollutes groundwater.<sup>34</sup>

This pollution shows up in small ponds which become choked with algae as a result of the unnatural influx of nutrients. From 1950 to 1990, the global consumption of artificial fertilizers rose by 1000%, from 14 million tons to 140 million tons.<sup>35</sup> In 1997, U.S. farmers used 20 million tons of synthetic fertilizers,<sup>36</sup> and half of all manufactured fertilizer ever made has been used just since 1982.<sup>37</sup> Nitrate pollution from excessive artificial fertilizer use is now one of the most serious water pollution problems in Europe and North America. Nitrate pollution can cause cancer and even brain damage or death in infants.<sup>38</sup> All the while, hundreds of millions of tons of compostable organic

materials are generated in the U.S. each year, and either buried in landfills, incinerated, or discharged into the environment as waste.

The squandering of our water resources, and pollution from sewage and synthetic fertilizers, results in part from the belief that humanure and food scraps are waste materials rather than recyclable natural resources. There is, however, an alternative. Humanure can undergo a process of bacterial digestion and then be returned to the soil. This process is usually known as *composting*. This is the missing link in the human nutrient recycling process.

*Raw* humanure carries with it a significant potential for danger in the form of disease pathogens. These diseases, such as intestinal parasites, hepatitis, cholera and typhoid are destroyed by composting, either when the retention time is adequate in a low temperature compost pile, or when the composting process generates internal, biological heat, which can kill pathogens in a matter of minutes.

*Raw* applications of humanure to fields are not hygienically safe and can assist in the spread of various diseases. Americans who have traveled to Asia tell of the “horrible stench” of night soil that wafts through the air when it is applied to fields. For these reasons, it is imperative that humanure always be composted before agricultural application. Proper composting destroys possible pathogens and results in a pleasant-smelling material.

On the other hand, raw night soil applications to fields in Asia do return humanure to the land, thereby recovering a valuable resource which is then used to produce food for humans. Cities in China, South Korea and Japan recycle night soil around their perimeters in greenbelts where vegetables are grown. Shanghai, China, a city with a population of 14.2 million people in 2000,<sup>39</sup> produces an exportable surplus of vegetables in this manner.

Humanure can also be used to feed algae which can, in turn, feed fish for aquacultural enterprises. In Calcutta, such an aquaculture system produces 20,000 kilograms of fresh fish daily.<sup>40</sup> The city of Tainan, Taiwan, is well known for its fish, which are farmed in over 6,000 hectares of fish farms fertilized by humanure. There, humanure is so valuable that it's sold on the black market.<sup>41</sup>

## RECYCLING HUMANURE

Humanure can be naturally recycled by feeding it to the organisms that crave it as food. These voracious creatures have been around for millions, and theoretically, *billions* of years. They've

patiently waited for us humans to discover them. Mother Nature has seeded our excrements, as well as our garbage, with these “friends in small places,” who will convert our organic discards into a soil-building material right before our eyes. Invisible helpers, these creatures are too small to be seen by the human eye and are therefore called *microorganisms*. The process of feeding organic material to these microorganisms in the presence of oxygen is called *composting*. Proper composting ensures the destruction of potential human pathogens (disease-causing microorganisms) in humanure. Composting also converts the humanure into a new, benign, pleasant-smelling and beneficial substance called *humus*, which is then returned to the soil to enrich it and enhance plant growth.

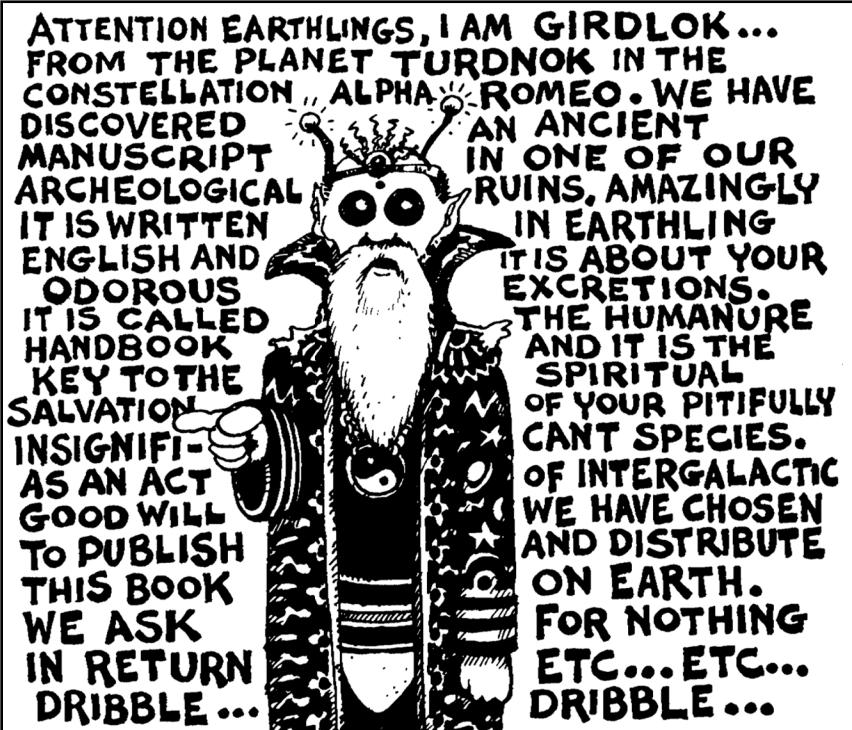
Incidentally, *all* animal manures benefit from composting, as today’s farmers are now discovering. Composted manures don’t leach like raw manures do. Instead, compost helps hold nutrients in soil systems. Composted manures also reduce plant disease and insect damage and allow for better nutrient management on farms. In fact, two tons of compost will yield far more benefits than five tons of manure.<sup>42</sup>

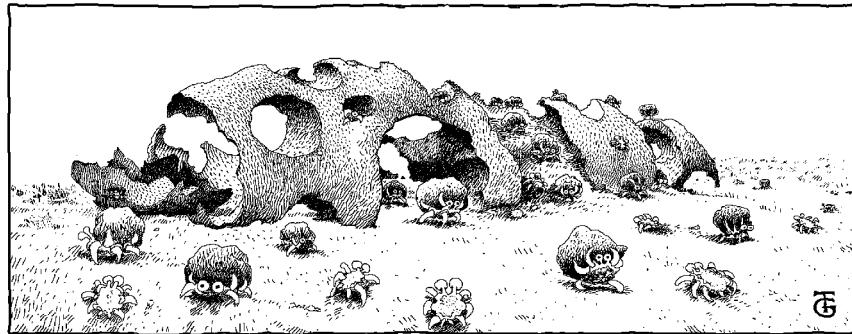
*Human* manure can be mixed with other organic materials from human activity such as kitchen and food scraps, grass clippings, leaves, garden refuse, paper products and sawdust. This mix of materials is necessary for proper composting to take place, and it will yield a soil additive suitable for food gardens as well as for agriculture.

One reason we humans have not “fed” our excrement to the appropriate organisms is because we didn’t know they existed. We’ve only learned to see and understand microscopic creatures in our recent past. We also haven’t had such a rapidly growing human population in the past, nor have we been faced with the dire environmental problems that threaten our species today like buzzards circling a dying animal.

It all adds up to the fact that the human species must inevitably evolve. Evolution means change, and change is often resisted as old habits die hard. Flush toilets and bulging garbage cans represent well entrenched habits that must be rethought and reinvented. If we humans are half as intelligent as we think we are, we’ll eventually get our act together. In the meantime, we’re realizing that nature holds many of the keys we need to unlock the door to a sustainable, harmonious existence on this planet. Composting is one of those keys, but it has only been relatively recently discovered by the human race. Its utilization is now beginning to mushroom worldwide.







# MICROHUSBANDRY

## Harnessing the Power of Microscopic Organisms

There are four general ways to deal with human excrement. The first is to *dispose of it* as a waste material. People do this by defecating in drinking water supplies, or in outhouses or latrines. Most of this waste ends up dumped, incinerated, buried in the ground, or discharged into waterways.

The second way to deal with human excrement is to *apply it raw to agricultural land*. This is popular in Asia where “night soil,” or raw human excrement, is applied to fields. Although this keeps the soil enriched, it also acts as a *vector*, or route of transmission, for disease organisms. In the words of Dr. J. W. Scharff, former chief health officer in Singapore, “*Though the vegetables thrive, the practice of putting human [manure] directly on the soil is dangerous to health. The heavy toll of sickness and death from various enteric diseases in China is well-known.*” It is interesting to note Dr. Scharff’s suggested alternative to the use of raw night soil: “*We have been inclined to regard the installation of a water-carried system as one of the final aims of civilization.*”<sup>1</sup> The World Health Organization also discourages the use of night soil: “*Night soil is sometimes used as a fertilizer, in which case it presents great hazards by*

*promoting the transmission of food-borne enteric [intestinal] disease, and hookworm.”<sup>2</sup>*

This book, therefore, is *not* about recycling night soil by raw applications to land, which is a practice that should be discouraged when sanitary alternatives, such as composting, are available.

The third way to deal with human excrement is to *slowly compost it over an extended period of time*. This is the way of most commercial composting toilets. Slow composting generally takes place at temperatures below that of the human body, which is 37°C or 98.6°F. This type of composting eliminates most disease organisms in a matter of months, and should eliminate all human pathogens eventually. Low temperature composting creates a useful soil additive that is at least safe for ornamental gardens, horticultural, or orchard use.

*Thermophilic* composting is the fourth way to deal with human excrement. This type of composting involves the cultivation of heat-loving, or *thermophilic*, microorganisms in the composting process. Thermophilic microorganisms, such as bacteria and fungi, can create an environment in the compost which destroys disease organisms that can exist in humanure, converting humanure into a friendly, pleasant-smelling humus safe for food gardens. Thermophilically composted humanure is *entirely different* from night soil.

Perhaps it is better stated by the experts in the field: “*From a survey of the literature of night soil treatment, it can be clearly concluded that the only fail-safe night soil method which will assure effective and essentially total pathogen inactivation, including the most resistant helminths [intestinal worms] such as Ascaris [roundworm] eggs and all other bacterial and viral pathogens, is heat treatment to a temperature of 55° to 60°C for several hours.*”<sup>3</sup> These experts are specifically referring to the heat of the *compost pile*.

## COMPOST DEFINED

According to the dictionary, compost is “*a mixture of decomposing vegetable refuse, manure, etc. for fertilizing and conditioning the soil.*” The Practical Handbook of Compost Engineering defines composting with a mouthful: “*The biological decomposition and stabilization of organic substrates, under conditions that allow development of thermophilic temperatures as a result of biologically produced heat, to produce a final product that is stable, free of pathogens and plant seeds, and can be beneficially applied to land.*”

The On-Farm Composting Handbook says that compost is “*a group of organic residues or a mixture of organic residues and soil that have been piled, moistened, and allowed to undergo aerobic biological decomposition.*”

The Compost Council adds their two-cents worth in defining compost: “*Compost is the stabilized and sanitized product of composting; compost is largely decomposed material and is in the process of humification (curing). Compost has little resemblance in physical form to the original material from which it is made.*” That last sentence should be particularly reassuring to the humanure composter.

J. I. Rodale states it a bit more eloquently: “*Compost is more than a fertilizer or a healing agent for the soil’s wounds. It is a symbol of continuing life . . . The compost heap is to the organic gardener what the typewriter is to the writer, what the shovel is to the laborer, and what the truck is to the truckdriver.*”<sup>4</sup>

In general, composting is a process managed by humans involving the cultivation of microorganisms that degrade and transform organic materials while in the presence of oxygen. When properly managed, the compost becomes so heavily populated with thermophilic microorganisms that it generates quite a bit of heat. Compost microorganisms can be so efficient at converting organic material into humus that the phenomenon is nothing short of miraculous.

## NATURALCHEMY

In a sense, we have a universe above us and one below us. The one above us can be seen in the heavens at night, but the one below us is invisible without magnifying lenses. Our ancestors had little understanding of the vast, invisible world which surrounded them, a world of countless creatures so small as to be quite beyond the range of human sight. And yet, some of those microscopic creatures were already doing work for humanity in the production of foods such as beer, wine, cheese, or bread. Although yeasts have been used by people for centuries, bacteria have only become harnessed by western humanity in recent times. Composting is one means by which the power of microorganisms can be utilized for the betterment of humankind. Prior to the advancement of magnification, our ancestors didn’t understand the role of microorganisms in the decomposition of organic matter, nor the efficacy of microscopic life in converting humanure, food scraps and plant residues into soil.

The composting of organic materials requires armies of bacteria. This microscopic force works so vigorously that it heats the material to temperatures hotter than are normally found in nature. Other micro (invisible) and macro (visible) organisms such as fungi and insects help in the composting process, too. When the compost cools down, earthworms often move in and eat their fill of delicacies, their excreta becoming a further refinement of the compost.

### SOLAR POWER IN A BANANA PEEL

Organic refuse contains stored solar energy. Every apple core or potato peel holds a tiny amount of heat and light, just like a piece of firewood. Perhaps S. Sides of the *Mother Earth News* states it more succinctly: “*Plants convert solar energy into food for animals (ourselves included). Then the [refuse] from these animals along with dead plant and animal bodies, ‘lie down in the dung heap,’ are composted, and ‘rise again in the corn.’ This cycle of light is the central reason why composting is such an important link in organic food production. It returns solar energy to the soil. In this context such common compost ingredients as onion skins, hair trimmings, eggshells, vegetable parings, and even burnt toast are no longer seen as garbage, but as sunlight on the move from one form to another.*”<sup>5</sup>

The organic material used to make compost could be considered anything on the Earth’s surface that had been alive, or from a living thing, such as manure, plants, leaves, sawdust, peat, straw, grass clippings, food scraps and urine. A rule of thumb is that anything that will rot will compost, including such things as cotton clothing, wool rugs, rags, paper, animal carcasses, junk mail and cardboard.

To compost means to convert organic material ultimately into soil or, more accurately, *humus*. Humus is a brown or black substance resulting from the decay of organic animal or vegetable refuse. It is a stable material that does not attract insects or nuisance animals. It can be handled and stored with no problem, and it is beneficial to the growth of plants. Humus holds moisture, and therefore increases the soil’s capacity to absorb and hold water. Compost is said to hold nine times its weight in water (900%), as compared to sand which only holds 2%, and clay 20%.<sup>6</sup>

Compost also adds slow-release nutrients essential for plant growth, creates air spaces in soil, helps balance the soil pH, darkens the soil (thereby helping it absorb heat), and supports microbial populations that add life to the soil. Nutrients such as nitrogen in com-

post are slowly released throughout the growing season, making them less susceptible to loss by leaching than the more soluble chemical fertilizers.<sup>7</sup> Organic matter from compost enables the soil to immobilize and degrade pesticides, nitrates, phosphorous and other chemicals that can become pollutants. Compost binds pollutants in soil systems, reducing their leachability and absorption by plants.<sup>8</sup>

The building of topsoil by Mother Nature is a centuries long process. Adding compost to soil will help to quickly restore fertility that might otherwise take nature hundreds of years to replace. We humans deplete our soils in relatively short periods of time. By composting our organic refuse and returning it to the land, we can restore that fertility also in relatively short periods of time.

Fertile soil yields better food, thereby promoting good health. The Hunzas of northern India have been studied to a great extent. Sir Albert Howard reported, “*When the health and physique of the various northern Indian races were studied in detail, the best were those of the Hunzas, a hardy, agile, and vigorous people living in one of the high mountain valleys of the Gilgit Agency . . . There is little or no difference between the kinds of food eaten by these hillmen and by the rest of northern India. There is, however, a great difference in the way these foods are grown . . . [T]he very greatest care is taken to return to the soil all human, animal and vegetable [refuse] after being first composted together. Land is limited: upon the way it is looked after, life depends.”*<sup>9</sup>

## GOMER THE PILE

There are several reasons for piling composting material. A pile keeps the material from drying out or cooling down prematurely. A high level of moisture (50-60%) is necessary for the microorganisms to work happily.<sup>10</sup> A pile prevents leaching and waterlogging, and holds heat. Vertical walls around a pile, especially if they’re made of wood or bales of straw, keep the wind off and will prevent one side of the pile (the windward side) from cooling down prematurely.

A neat, contained pile looks better. It looks like you know what you’re doing when making compost, instead of looking like a garbage dump. A constructed compost bin also helps to keep out nuisance animals such as dogs.

A pile makes it easier to layer or cover the compost. When a smelly deposit is added to the top of the pile, it’s essential to cover it with clean organic material to eliminate unpleasant odors and to help trap necessary oxygen in the pile. Therefore, if you’re going to make

compost, don't just fling it out in your yard in a heap. Construct a nice bin and do it right. That bin doesn't have to cost money; it can be made from recycled wood or cement blocks. Wood may be preferable as it will insulate the pile and prevent heat loss and frost penetration. Avoid woods that have been soaked in toxic chemicals.

A backyard composting system doesn't have to be complicated in any way. It doesn't require electricity, technology, gimmicks or doodads. You don't need shredders, choppers, grinders or any machines whatsoever.

## FOUR NECESSITIES FOR GOOD COMPOST

### 1) MOISTURE

Compost must be kept moist. A dry pile will not work — it will just sit there and look bored. It's amazing how much moisture an active compost pile can absorb. When people who don't have any experience with compost try to picture a humanure compost pile in someone's backyard, they imagine a giant, fly-infested, smelly heap of excrement, draining all manner of noxious, stinky liquids out of the bottom of the compost pile. However, a compost pile is not a pile of garbage or waste. Thanks to the miracle of composting, the pile becomes a living, breathing, biological mass, an organic sponge that absorbs quite a bit of moisture. The pile is not likely to create a leaching problem unless subjected to sustained heavy rains — then it can simply be covered.

Why do compost piles require moisture? For one thing, compost loses a lot of moisture into the air during the composting process, which commonly causes a compost pile to shrink 40-80%<sup>11</sup>. Even when wet materials are composted, a pile can undergo considerable drying.<sup>12</sup> An initial moisture content of 65% can dwindle down to 20 to 30% in only a week, according to some researchers.<sup>13</sup> It is more likely that one will have to *add* moisture to one's compost than have to deal with excess moisture leaching from it.

The amount of moisture a compost pile receives or needs depends on the materials put into the pile as well as the location of the pile. In Pennsylvania, there are about 36 inches (one meter) of rainfall each year. Compost piles rarely need watering under these conditions. According to Sir Albert Howard, watering a compost pile in an area of England where the annual rainfall is 24 inches is also unnecessary. Nevertheless, the water required for compost-making

may be around 200 to 300 gallons for each cubic yard of finished compost.<sup>14</sup> This moisture requirement will be met when human urine is used in humanure compost and the top of the pile is uncovered and receiving adequate rainfall. Additional water can come from moist organic materials such as food scraps. If adequate rainfall is not available and the contents of the pile are not moist, watering will be necessary to produce a moisture content equivalent to a squeezed-out sponge. Graywater from household drains or collected rainwater would suffice for this purpose.

## 2) OXYGEN

Compost requires the cultivation of *aerobic*, or oxygen loving, bacteria in order to ensure thermophilic decomposition. This is done by adding bulky materials to the compost pile in order to create tiny interstitial air spaces. Aerobic bacteria will suffer from a lack of oxygen if drowned in liquid.

Bacterial decomposition can also take place anaerobically, but this is a slower, cooler process which can, quite frankly, stink. Anaerobic odors can smell like rotten eggs (caused by hydrogen sulfide), sour milk (caused by butyric acids), vinegar (acetic acids), vomit (valeic acids), and putrification (alcohols and phenolic compounds).<sup>15</sup> Obviously, we want to avoid such odors by maintaining an aerobic compost pile.

Good, healthy, aerobic compost need not offend one's sense of smell. However, in order for this to be true, a simple rule must be followed: *anything added to a compost pile that smells bad must be covered with a clean, organic, non-smelly material*. If you're using a compost toilet, then you must cover the deposits in your toilet after each use. You must likewise cover your compost pile each time you add material to it. Good compost toilet cover materials include sawdust, peat moss, leaves, rice hulls, coco coir and lots of other things. Good cover materials for a compost pile include weeds, straw, hay, leaves and other bulky material which will help trap oxygen in the compost. Adequately covering compost with a clean organic material is the simple secret to odor prevention. It also keeps flies off the compost.

## 3) TEMPERATURE

Dehydration will cause the compost microorganisms to stop working. So will freezing. Compost piles will not work if frozen.

## BENEFITS OF COMPOST

### ENRICHES SOIL

- Adds organic material
- Improves fertility and productivity
- Suppresses plant diseases
- Discourages insects
- Increases water retention
- Inoculates soil with beneficial microorganisms
- Reduces or eliminates fertilizer needs
- Moderates soil temperature

### PREVENTS POLLUTION

- Reduces methane production in landfills
- Reduces or eliminates organic garbage
- Reduces or eliminates sewage

### FIGHTS EXISTING POLLUTION

- Degrades toxic chemicals
- Binds heavy metals
- Cleans contaminated air
- Cleans stormwater runoff

### RESTORES LAND

- Aids in reforestation
- Helps restore wildlife habitats
- Helps reclaim mined lands
- Helps restore damaged wetlands
- Helps prevent erosion on flood plains

### DESTROYS PATHOGENS

- Can destroy human disease organisms
- Can destroy plant pathogens
- Can destroy livestock pathogens

### SAVES MONEY

- Can be used to produce food
- Can eliminate waste disposal costs
- Reduces the need for water, fertilizers, and pesticides
- Can be sold at a profit
- Extends landfill life by diverting materials
- Is a less costly bioremediation technique

Source: U.S. EPA (October 1997). *Compost-New Applications for an Age-Old Technology*. EPA530-F-97-047. And author's experience.

However, the microorganisms can simply wait until the temperature rises enough for them to thaw out and then they'll work feverishly. If you have room, you can continue to add material to a frozen compost pile. After a thaw, the pile should work up a steam as if nothing happened.

### 4) BALANCED DIET

A good blend of materials (a good *carbon/nitrogen balance* in compost lingo) is required for a nice, hot compost pile. Since most of the materials commonly added to a backyard compost pile are high in carbon, a source of nitrogen must be incorporated into the blend of ingredients. This isn't as difficult as it may seem. You can carry bundles of weeds to your compost pile, add hay, straw, leaves and food scraps, but you may still be short on nitrogen. Of course the solution is simple — add manure. Where can you get manure? From an animal. Where can you find an animal? *Look in a mirror.*

Rodale states in *The Complete Book of Composting* that the average gardener may have difficulty in obtaining manure for the compost heap, but with "*a little ingenuity and a thorough search,*" it can be found. A gardener in the book testifies that

when he gets “*all steamed up to build myself a good compost pile, there has always been one big question that sits and thumbs its nose at me: Where am I going to find the manure? I am willing to bet, too, that the lack of manure is one of the reasons why your compost pile is not the thriving humus factory that it might be.*”

Hmmm. *Where* can a large animal like a human being find manure? Gee, that’s a tough one. Let’s think real hard about that. Perhaps with a little “ingenuity and a thorough search” we can come up with a source. *Where is* that mirror, anyway? Might be a clue there.

## THE CARBON/NITROGEN RATIO

One way to understand the blend of ingredients in your compost pile is by using the C/N ratio (carbon/nitrogen ratio). Quite frankly, the chance of the average person measuring and monitoring the carbon and nitrogen quantities of her organic material is almost nil. If composting required this sort of drudgery, no one would do it.

However, by using all of the organic refuse a family produces, including humanure, urine, food refuse, weeds from the garden, and grass clippings, with some materials from the larger agricultural community such as a little straw or hay, and maybe some rotting sawdust or some collected leaves from the municipality, one can get a good mix of carbon and nitrogen for successful thermophilic composting.

A good C/N ratio for a compost pile is between 20/1 and 35/1.<sup>16</sup> That’s 20 parts of carbon to one part of nitrogen, up to 35 parts of carbon to one part of nitrogen. Or, for simplicity, you can figure on shooting for an optimum 30/1 ratio.

For microorganisms, carbon is the basic building block of life and is a source of energy, but nitrogen is also necessary for such things as proteins, genetic material and cell structure. For a balanced diet, microorganisms that digest compost need about 30 parts of carbon for every part of nitrogen they consume. If there’s too much nitrogen, the microorganisms can’t use it all and the excess is lost in the form of smelly ammonia gas. Nitrogen loss due to excess nitrogen in a compost pile (a low C/N ratio) can be over 60%. At a C/N ratio of 30 or 35 to 1, only one half of one percent of the nitrogen will be lost (see Table 3.1). That’s why you don’t want too much nitrogen in your compost — the nitrogen will be lost to the air in the form of ammonia gas, and nitrogen is too valuable for plants to allow it to escape into the atmosphere.<sup>17</sup>

Table 3.2  
**CARBON/NITROGEN RATIOS**

<u>Material</u>	<u>%N</u>	<u>C/N Ratio</u>	
Activated Sldg.	5-6	6	Red Clover ..... 1.8 ..... 27
Amaranth	3.6	11	Rice Hulls ..... 0.3 ..... 121
Apple Pomace	1.1	13	Rotted Sawdust ... 0.25 ... 200-500
Blood	10-14	3	Seaweed ..... 1.9 ..... 19
Bread	2.10	---	Sewage Sludge ... 2-6.9 ... 5-16
Cabbage	3.6	12	Sheep Manure .... 2.7 ..... 16
Cardboard	0.10	400-563	Shrimp Residues .. 9.5 ..... 3.4
Coffee Grnds.	--	20	Slaughter Waste .. 7-10 ..... 2-4
Cow Manure	2.4	19	Softwood Bark .... 0.14 ..... 496
Corn Cobs	0.6	56-123	Softwoods (Avg.) .. 0.09 ..... 641
Corn Stalks	0.6-0.8	60-73	Soybean Meal .... 7.2-7.6 ..... 4-6
Cottonseed Ml.	7.7	7	Straw (General) ... 0.7 ..... 80
Cranberry Plant	0.9	61	Straw (Oat) ..... 0.9 ..... 60
Farm Manure	2.25	14	Straw (Wheat) .... 0.4 ..... 80-127
Fern	1.15	43	Telephone Books .. 0.7 ..... 772
Fish Scrap	10.6	3.6	Timothy Hay ..... 0.85 ..... 58
Fruit	1.4	40	Tomato ..... 3.3 ..... 12
Garbage (Raw)	2.15	15-25	Turkey Litter ..... 2.6 ..... 16
Grass Clippings	2.4	12-19	Turnip Tops ..... 2.3 ..... 19
Hardwood Bark	0.241	223	Urine ..... 15-18 ..... 0.8
Hardwoods (Avg)	0.09	560	Vegetable Prod. .... 2.7 ..... 19
Hay (General)	2.10	---	Water Hyacinth ..... --- ..... 20-30
Hay (legume)	2.5	16	Wheat Straw ..... 0.3 ..... 128-150
Hen Manure	8	6-15	Whole Carrot ..... 1.6 ..... 27
Horse Manure	1.6	25-30	Whole Turnip ..... 1.0 ..... 44
Humanure	5-7	5-10	
Leaves	0.9	54	
Lettuce	3.7	---	
Meat Scraps	5.1	---	
Mussel Resid.	3.6	2.2	
Mustard	1.5	26	
Newsprint	.06-14	398-852	
Oat Straw	1.05	48	
Olive Husks	1.2-1.5	30-35	
Onion	2.65	15	
Paper	--	100-800	
Pepper	2.6	15	
Pig Manure	3.1	14	
Potato Tops	1.5	25	
Poultry Carcasses	2.4	5	
Purslane	4.5	8	
Raw Sawdust	0.11	511	

Table 3.1  
**NITROGEN LOSS AND  
CARBON/NITROGEN RATIO**

<u>Initial C/N Ratio</u>	<u>Nitrogen Loss (%)</u>
20.0	38.8
20.5	48.1
22.0	14.8
30.0	0.5
35.0	0.5
76.0	-8.0

Source: Gotaas, *Composting*, 1956, p. 92

Sources: Gotaas, Harold B. (1956). *Composting - Sanitary Disposal and Reclamation of Organic Wastes* (p.44). World Health Organization, Monograph Series Number 31. Geneva. and Rynk, Robert, ed. (1992). *On-Farm Composting Handbook*. Northeast Regional Agricultural Engineering Service, Ph: (607) 255-7654. pp. 106-113. Some data from Biocycle, Journal of Composting and Recycling, July 1998, p.18, 61, 62; and January 1998, p.20.

Table 3.5  
**COMPARISONS OF DIFFERENT TYPES OF MANURES**

<u>Manure</u>	<u>% Moisture</u>	<u>% N</u>	<u>% Phos</u>	<u>% K</u>
Human	66-80	5-7	3-5.4	1.0-2.5
Cattle	80	1.67	1.11	0.56
Horse	75	2.29	1.25	1.38
Sheep	68	3.75	1.87	1.25
Pig	82	3.75	1.87	1.25
Hen	56	6.27	5.92	3.27
Pigeon	52	5.68	5.74	3.23
Sewage	---	5-10	2.5-4.5	3.0-4.5

Source: Gotaas, Harold B. (1956). *Composting - Sanitary Disposal and Reclamation of Organic Wastes.* pp. 35, 37, 40. World Health Organization, Monograph Series Number 31. Geneva.

Table 3.3  
**COMPOSITION OF HUMANURE**

FECAL MATERIAL	
0.3-0.6 pounds/person/day (135-270 grams), wet weight	
Organic Matter (dry wt.)	88-97%
Moisture Content	66-80%
Nitrogen	5-7%
Phosphorous	3-5.4%
Potassium	1-2.5%
Carbon	40-55%
Calcium	4-5%
C/N Ratio	5-10

URINE  
1.75-2.25 pints per person per day  
(1.0-1.3 liters)

Moisture	93-96%
Nitrogen	15-19%
Phosphorous	2.5-5%
Potassium	3-4.5%
Carbon	11-17%
Calcium	4.5-6%

Source: Gotaas, Composting, (1956), p. 35.

Table 3.4  
**DECOMPOSITION RATES OF SELECTED SAWDUSTS**

<u>SAWDUST</u>	<u>RELATIVE DECOMPOSITION RATE</u>
Red Cedar	3.9
Douglas Fir	8.4
White Pine	9.5
Western White Pine	22.2
Average of all softwoods	12.0
Chestnut	33.5
Yellow Poplar	44.3
Black Walnut	44.7
White Oak	49.1
Average of all hardwoods	45.1
Wheat straw	54.6

The lower the number, the slower the decomposition rate. Hardwood sawdust decomposes faster than softwood sawdust.

Source: Haug, Roger T. (1993). *The Practical Handbook of Compost Engineering.* CRC Press, Inc., 2000 Corporate Blvd. N.W., Boca Raton, FL 33431 U.S.A. as reported in Biocycle - Journal of Composting and Recycling. December, 1998. p. 19.

That's also why humanure and urine alone *will not* compost. They contain too much nitrogen and not enough carbon, and microorganisms, like humans, gag at the thought of eating it. Since there's nothing worse than the thought of several billion gagging microorganisms, a carbon-based material must be added to the humanure in order to make it into an appealing dinner. Plant cellulose is a carbon-based material, and therefore plant by-products such as hay, straw, weeds or even paper products if ground to the proper consistency, will provide the needed carbon. Kitchen food scraps are generally C/N balanced, and they can be readily added to humanure compost. Sawdust (preferably not kiln-dried) is a good carbon material for balancing the nitrogen of humanure.

Sawmill sawdust has a moisture content of 40-65%, which is good for compost.<sup>18</sup> Lumber yard sawdust, on the other hand, is kiln-dried and is biologically inert due to dehydration. Therefore, it is not as desirable in compost unless rehydrated with water (or urine) before being added to the compost pile. Also, lumber yard sawdust nowadays can often be contaminated with wood preservatives such as chromated copper arsenate (from "pressure treated lumber"). Both chromium and arsenic are human carcinogens, so it would be wise to avoid such lumber — now banned by the EPA.

Some backyard composters refer to organic materials as "browns" and "greens." The browns (such as dried leaves) supply carbon, and the greens (such as fresh grass clippings) supply nitrogen. It's recommended that two to three volumes of browns be mixed with one volume of greens in order to produce a mix with the correct C/N ratio for composting.<sup>19</sup> However, since most backyard composters are not humanure composters, many have a pile of material sitting in their compost bin showing very little activity. What is usually missing is nitrogen as well as moisture, two critical ingredients to any compost pile. Both of these are provided by humanure when collected with urine and a carbon cover material. The humanure mix can be quite brown, but is also quite high in nitrogen. So the "brown/green" approach doesn't really work, nor is it necessary, when composting humanure along with other household organic material. Let's face it, humanure composters are in a class by themselves.

## THERMOPHILIC MICROORGANISMS

A wide array of microorganisms live in a compost pile. Bacteria are especially abundant and are usually divided into several classes based upon the temperatures at which they best thrive. The low temperature bacteria are the *psychrophiles*, which can grow at temperatures down to -10°C, but whose optimum temperature is 15°C (59°F) or lower. The *mesophiles* live at medium temperatures, 20-45°C (68-113°F), and include human pathogens. *Thermophiles* thrive above 45°C (113°F), and some live at, or even above, the boiling point of water.

Strains of thermophilic bacteria have been identified with optimum temperatures ranging from 55°C to an incredible 105°C (above the boiling point of water), and many temperatures in between.<sup>20</sup> The strains that survive at extremely high temperatures are called, appropriately enough, extreme thermophiles, or hyperthermophiles, and have a temperature optimum of 80°C (176°F) or higher. Thermophilic bacteria occur naturally in hot springs, tropical soils, compost heaps, in your excrement, in hot water heaters (both domestic and industrial), and in your garbage, to name a few places.<sup>21</sup>

Thermophilic bacteria were first isolated in 1879 by Miquel, who found bacteria capable of developing at 72°C (162°F). He found these bacteria in soil, dust, *excrement*, sewage, and river mud. It wasn't long afterward that a variety of thermophilic bacteria were discovered in soil — bacteria that readily thrived at high temperatures, but not at room temperature. These bacteria are said to be found in the sands of the Sahara Desert, but not in the soil of cool forests. Composted or manured garden soils may contain 1-10 percent thermophilic types of bacteria, while field soils may have only 0.25% or less. Uncultivated soils may be entirely free of thermophilic bacteria.<sup>22</sup>

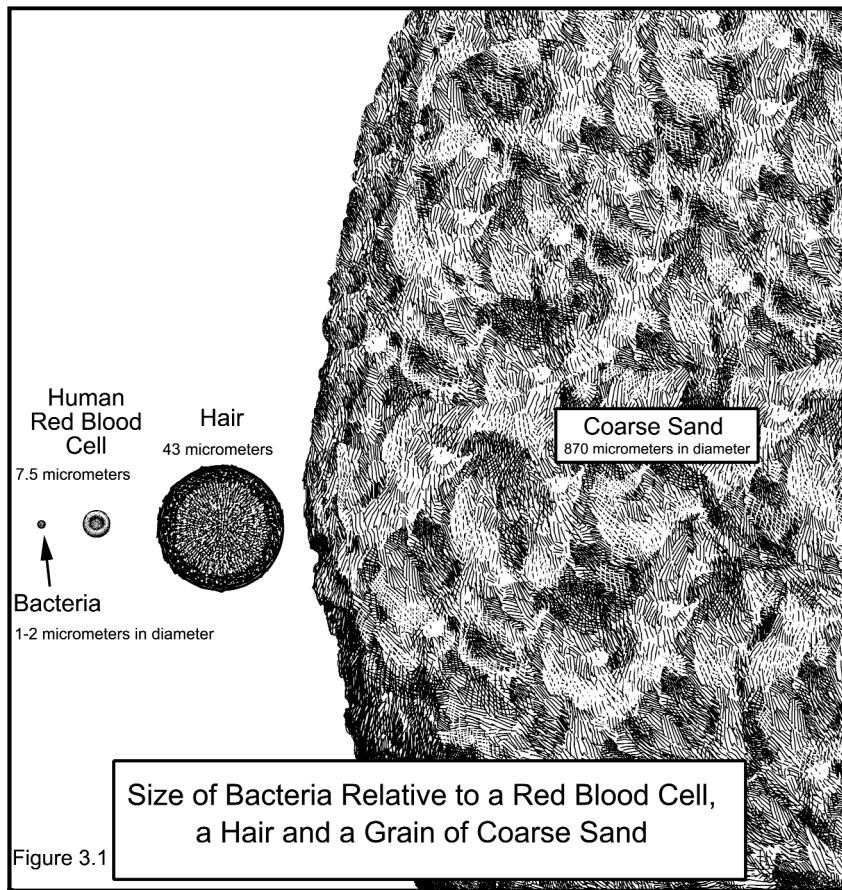
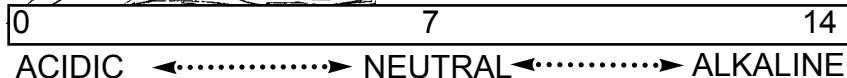
Thermophiles are responsible for the spontaneous heating of hay stacks which can cause them to burst into flame. Compost itself can sometimes spontaneously combust. This occurs in larger piles (usually over 12 feet high) that become too dry (between 25% and 45% moisture) and then overheat.<sup>23</sup> Spontaneous fires have started at two American composting plants — Schenectady and Cape May — due to excessively dry compost. According to the EPA, fires can start at surprisingly low temperatures (194°F) in too-dry compost, although this is not a problem for the backyard composter. When growing on bread, thermophiles can raise the temperature of the

## ESSENTIAL READING FOR INSOMNIACS



### pH MEANS HYDROGEN POWER

It is a measure of the degree of alkalinity or acidity of a solution, and is often expressed as the logarithm of the reciprocal of the hydrogen ion concentration in gram equivalents per liter of solution.  $\text{pH} = -\log[\text{H}^+]$ . Pure distilled water is regarded as neutral with a pH of 7. pH values range from 0 to 14. From 0 to 7 indicate acidity, and from 7 to 14 indicate alkalinity.



Source: Gest, Howard (1993). Vast Chain of Being. Perspectives in Biology and Medicine. Volume 36, No. 22, Winter 1993. University of Chicago, Division of Biological Sciences. p. 186.

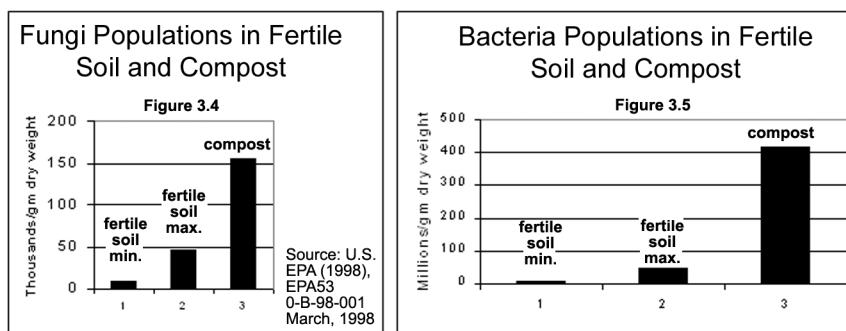
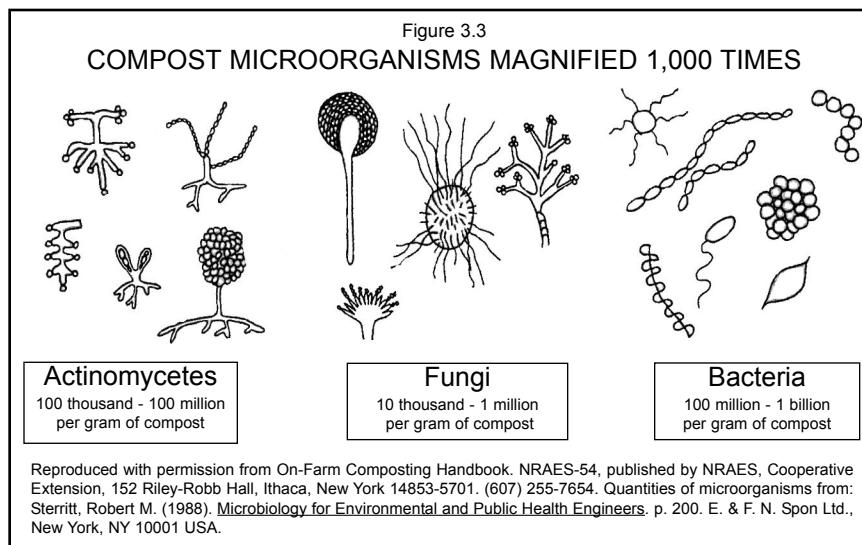


Table 3.6  
MICROORGANISMS IN COMPOST

<u>Actinomycetes</u>	<u>Fungi</u>	<u>Bacteria</u>
<i>Actinobifida chromogena</i>	<i>Aspergillus fumigatus</i>	<i>Alcaligenes faecalis</i>
<i>Microbispora bispora</i>	<i>Humicola grisea</i>	<i>Bacillus brevis</i>
<i>Micropolyspora faeni</i>	<i>H. insolens</i>	<i>B. circulans complex</i>
<i>Nocardia</i> sp.	<i>H. lanuginosa</i>	<i>B. coagulans type A</i>
<i>Pseudocardia thermophilia</i>	<i>Malbranchea pulchella</i>	<i>B. coagulans type B</i>
<i>Streptomyces rectus</i>	<i>Myriococcum thermophilum</i>	<i>B. licheniformis</i>
<i>S. thermofuscus</i>	<i>Paecilomyces variotti</i>	<i>B. megaterium</i>
<i>S. thermoviolaceus</i>	<i>Papulaspora thermophila</i>	<i>B. pumilus</i>
<i>S. thermovulgaris</i>	<i>Scytalidium thermophilum</i>	<i>B. sphaericus</i>
<i>S. violaceus-ruber</i>	<i>Sporotrichum thermophile</i>	<i>B. stearothermophilus</i>
<i>Thermoactinomyces sacchari</i>		<i>B. subtilis</i>
<i>T. vulgaris</i>		<i>Clostridium thermocellum</i>
<i>Thermomonospora curvata</i>		<i>Escherichia coli</i>
<i>T. viridis</i>		<i>Flavobacterium</i> sp.
		<i>Pseudomonas</i> sp.
		<i>Serratia</i> sp.
		<i>Thermus</i> sp.

Source: Palmisano, Anna C. and Barlaz, Morton A. (Eds.) (1996). *Microbiology of Solid Waste*. Pp. 125-127. CRC Press, Inc., 2000 Corporate Blvd., N.W., Boca Raton, FL 33431 USA.

bread to 74°C (165°F). Heat from bacteria also warms germinating seeds, as seeds in a sterile environment are found to remain cool while germinating.<sup>24</sup>

Both mesophilic and thermophilic microorganisms are found widely distributed in nature and are commonly resident on food material, garbage and manures. This is not surprising for mesophiles because the temperatures they find to be optimum for their reproduction are commonly found in nature. These temperatures include those of warm-blooded animals, which excrete mesophiles in their stools in huge numbers.

A mystery presents itself, on the other hand, when we consider *thermophilic* microorganisms, since they prefer living at temperatures not commonly found in nature, such as hot springs, water heaters and compost piles. Their preference for hot temperatures has given rise to some speculation about their evolution. One theory suggests that the thermophiles were among the first living things on this planet, developing and evolving during the primordial birthing of the Earth when surface temperatures were quite hot. They have thus been called the “Universal Ancestor.” Estimated at 3.6 billion years old, they are said to be so abundant as to “comprise as much as half of all living things on the planet.”<sup>25</sup> This is a rather profound concept, as it would mean that thermophilic organisms are perhaps more ancient than any other living thing. Their age would make dinosaurs look like new-born babes still wet behind the ears, however extinct. Of course, we humans, in comparison, have just shown up on Earth. Thermophiles could therefore be the common ancestral organism of all life forms on our planet.

Just as extraordinary is the concept that thermophiles, despite their need for a hot environment, are found everywhere. They’re lingering in your garbage and in your stool and have been since we humans first began to crawl on this planet. They have quietly waited since the beginning of time, and we haven’t been aware of them until recently. Researchers insist that thermophiles do not grow at ambient or room temperatures.<sup>26</sup> Yet, like a miracle, when we collect our organic refuse in a tidy pile, the thermophiles seem to be sparked out of their dormant slumber to work furiously toward creating the primordial heat they so desire. And they succeed — if we help them by creating compost piles. They reward us for our help by converting our garbage and other organic discards into life-sustaining earth.

The knowledge of living creatures incomprehensibly ancient,

so small as to be entirely invisible, thriving at temperatures hotter than those normally found in nature, and yet found alive everywhere, is remarkable enough. The fact that they are so willing to work for our benefit, however, is rather humbling.

By some estimates, humanure contains up to a trillion (1,000,000,000,000) bacteria per gram.<sup>27</sup> These are, of course, mixed species, and not by any means all thermophiles. A trillion bacteria is equivalent to the entire human population of the Earth multiplied by 166, and all squeezed into a gram of organic material. These microbiological concepts of size and number are difficult for us humans to grasp. Ten people crammed into an elevator we can understand. A trillion living organisms in a teaspoonful of crap is a bit mind-boggling.

Has anyone identified the species of microorganism that heats up compost? Actually, a large variety of species, a *biodiversity*, is critical to the success of compost. However, the thermophilic stage of the process is dominated by thermophilic bacteria. One examination of compost microorganisms at two compost plants showed that most of the bacteria (87%) were of the genus *Bacillus*, which are bacteria that form spores,<sup>28</sup> while another researcher found that above 65°C, the organisms in the compost were almost purely *Bacillus stearothermophilus*.<sup>29</sup>

#### FOUR STAGES OF COMPOST

There is a huge difference between a backyard humanure composter and a municipal composter. Municipal composters handle large batches of organic materials all at once, while backyard composters continuously produce a small amount of organic material every day. Municipal composters, therefore, are “batch” composters, while backyard composters tend to be “continuous” composters. When organic material is composted in a batch, four distinct stages of the composting process are apparent. Although the same phases occur during continuous composting, they are not as apparent as they are in a batch, and in fact they may be occurring concurrently rather than sequentially.

The four phases include: 1) the mesophilic phase; 2) the thermophilic phase; 3) the cooling phase; and 4) the curing phase.

Compost bacteria combine carbon with oxygen to produce carbon dioxide and energy. Some of the energy is used by the microorganisms for reproduction and growth; the rest is given off as

heat. When a pile of organic refuse begins to undergo the composting process, mesophilic bacteria proliferate, raising the temperature of the composting mass up to 44°C (111°F). This is the first stage of the composting process. These mesophilic bacteria can include *E. coli* and other bacteria from the human intestinal tract, but these soon become increasingly inhibited by the temperature, as the thermophilic bacteria take over in the transition range of 44°C-52°C (111°F-125.6°F).

This begins the second stage of the process, when thermophilic microorganisms are very active and produce a lot of heat. This stage can then continue to about 70°C (158°F),<sup>30</sup> although such high temperatures are neither common nor desirable in backyard compost. This heating stage takes place rather quickly and may last only a few days, weeks or months. It tends to remain localized in the upper portion of a backyard compost bin where the fresh material is being added; whereas in batch compost, the entire composting mass may be thermophilic all at once.

After the thermophilic heating period, the humanure will appear to have been digested, but the coarser organic material will not. This is when the third stage of composting, the cooling phase, takes place. During this phase, the microorganisms that were chased away by the thermophiles migrate back into the compost and get to work digesting the more resistant organic materials. Fungi and macroorganisms such as earthworms and sowbugs also break the coarser elements down into humus.

After the thermophilic stage has been completed, only the readily available nutrients in the organic material have been digested. There's still a lot of food in the pile, and a lot of work to be done by the creatures in the compost. It takes many months to break down some of the more resistant organic materials in compost such as "lignin," which comes from wood materials. Like humans, trees have evolved with a skin that is resistant to bacterial attack, and in a compost pile these lignins resist breakdown by thermophiles. However, other organisms, such as fungi, can break down lignin, given enough time; since many fungi don't like the heat of thermophilic compost, they simply wait for things to cool down before beginning their job.

The final stage of the composting process is called the curing, aging or maturing stage, and it is a long and important one. Commercial composting professionals often want to make their compost as quickly as possible, usually sacrificing the compost's curing time. One municipal compost operator remarked that if he could

shorten his compost time to four months, he could make three batches of compost a year instead of only the two he was then making, thereby increasing his output by 50%. Municipal composters see truckloads of compost coming in to their facilities daily, and they want to make sure they don't get inundated with organic material waiting to be composted. Therefore, they feel a need to move their material through the composting process as quickly as possible to make room for the new stuff. Household composters don't have that problem, although there seem to be plenty of backyard composters who are obsessed with making compost as quickly as possible. However, the curing of the compost is a critically important stage of the compost-making process.

A long curing period, such as a year after the thermophilic stage, adds a safety net for pathogen destruction. Many human pathogens have only a limited period of viability in the soil, and the longer they are subjected to the microbiological competition of the compost pile, the more likely they will die a swift death.

Immature or uncured compost can produce substances called *phytotoxins* that are toxic to plants. It can also rob the soil of oxygen and nitrogen and can contain high levels of organic acids. So relax, sit back, put your feet up, and let your compost reach full maturity *before* you even think about using it.

## COMPOST BIODIVERSITY

Compost is normally populated by three general categories of microorganisms: bacteria, actinomycetes and fungi (see Figure 3.3 and Table 3.6). It is primarily the bacteria, and specifically the thermophilic bacteria, that create the heat of the compost pile.

Although considered bacteria, actinomycetes are effectively intermediates between bacteria and fungi because they look similar to fungi and have similar nutritional preferences and growth habits. They tend to be more commonly found in the later stages of compost, and are generally thought to follow the thermophilic bacteria in succession. They, in turn, are followed predominantly by fungi during the last stages of the composting process.

There are at least 100,000 known species of fungi, the overwhelming majority of them being microscopic.<sup>31</sup> Most fungi cannot grow at 50°C because it's too hot, although *thermophilic fungi* are heat tolerant. Fungi tend to be absent in compost above 60°C and actinomycetes tend to be absent above 70°C. Above 82°C biological activity

effectively stops (extreme thermophiles are not found in compost).<sup>32</sup>

To get an idea of the microbial diversity normally found in nature, consider this: a teaspoon of native grassland soil contains 600-800 million bacteria comprising 10,000 species, plus perhaps 5,000 species of fungi, the mycelia of which could be stretched out for several miles. In the same teaspoon, there may be 10,000 individual protozoa of perhaps 1,000 species, plus 20-30 different nematodes from as many as 100 species. Sounds crowded to me. Obviously, good compost will reinoculate depleted, sanitized, chemicalized soils with a wide variety of beneficial microorganisms (see Figures 3.4 and 3.5).<sup>33</sup>

#### COMPOST MICROORGANISMS “SANITIZE” COMPOST

A frequent question is, “How do you know that *all* parts of your compost pile have been subjected to high enough temperatures to kill *all* potential pathogens?” The answer should be obvious: you don’t. You never will. Unless, of course, you examine every cubic centimeter of your compost for pathogens in a laboratory. This would probably cost many thousands of dollars, which would make your compost the most expensive in history.

It’s not only the *heat* of the compost that causes the destruction of human, animal and plant pathogens, it’s a combination of factors, including:

- competition for food from compost microorganisms;
- inhibition and antagonism by compost microorganisms;
- consumption by compost organisms;
- biological heat generated by compost microorganisms; and
- antibiotics produced by compost microorganisms.

For example, when bacteria were grown in an incubator without compost at 50°C and separately in compost at 50°C, they died in the compost after only seven days, but lived in the incubator for seventeen days. This indicated that it is more than just temperature that determines the fate of pathogenic bacteria. The other factors listed above undoubtedly affect the viability of non-indigenous microorganisms, such as human pathogens, in a compost pile. Those factors require as large and diverse a microbial population as possible, which is best achieved by temperatures below 60°C (140°F). One researcher states that, “*Significant reductions in pathogen numbers have been observed in compost piles which have not exceeded 40°C [104°F].*”<sup>34</sup>

There is no doubt that the heat produced by thermophilic bacteria kills pathogenic microorganisms, viruses, bacteria, protozoa, worms and eggs that may inhabit humanure. A temperature of 50°C (122° F), if maintained for twenty-four hours, is sufficient to kill all of the pathogens, according to some sources (this issue is covered in Chapter Seven). A lower temperature will take longer to kill pathogens. A temperature of 46°C (115°F) may take nearly a week to kill pathogens completely; a higher temperature may take only minutes. What we have yet to determine is how low those temperatures can be and still achieve satisfactory pathogen elimination. Some researchers insist that all pathogens will die at ambient temperatures (normal air temperature) given enough time.

When Westerberg and Wiley composted sewage sludge which had been inoculated with polio virus, *Salmonella*, roundworm eggs, and *Candida albicans*, they found that a compost temperature of 47-55°C (116-130°F) maintained for three days killed all of these pathogens.<sup>35</sup> This phenomenon has been confirmed by many other researchers, including Gotaas, who indicates that pathogenic organisms are unable to survive compost temperatures of 55-60°C (131-140°F) for more than thirty minutes to one hour.<sup>36</sup> The first goal in composting humanure, therefore, should be to create a compost pile that will heat sufficiently to kill potential human pathogens that may be found in the manure.

Nevertheless, the heat of the compost pile is a highly lauded characteristic of compost that can be a bit overblown at times. People may believe that it's *only* the heat of the compost pile that destroys pathogens, so they want their compost to become as hot as possible. This is a mistake. In fact, compost can become too hot, and when it does, it destroys the biodiversity of the microbial community. As one scientist states, "*Research has indicated that temperature is not the only mechanism involved in pathogen suppression, and that the employment of higher than necessary temperatures may actually constitute a barrier to effective sanitization under certain circumstances.*"<sup>37</sup> Perhaps only one species (e.g., *Bacillus stearothermophilus*) may dominate the compost pile during periods of excessive heat, thereby driving out or outright killing the other inhabitants of the compost, which include fungi and actinomycetes as well as the bigger organisms that you can actually see.

A compost pile that is too hot can destroy its own biological community and leave a mass of organic material that must be re-populated in order to continue the necessary conversion of organic mat-

ter to humus. Such sterilized compost is more likely to be colonized by unwanted microorganisms, such as *Salmonella*. Researchers have shown that the biodiversity of compost acts as a barrier to colonization by such unwanted microorganisms as *Salmonella*. In the absence of a biodiverse “indigenous flora,” such as caused by sterilization due to excess heat, *Salmonella* were able to regrow.<sup>38</sup>

The microbial biodiversity of compost is also important because it aids in the breakdown of the organic material. For example, in high-temperature compost (80°C), only about 10% of sewage sludge solids could be decomposed in three weeks, whereas at 50-60°C, 40% of the sludge solids were decomposed in only seven days. The lower temperatures apparently allowed for a richer diversity of living things which in turn had a greater effect on the degradation of the organic matter. One researcher indicates that optimal decomposition rates occur in the 55-59°C (131-139°F) temperature range, and optimal thermophilic activity occurs at 55°C (131°F), which are both adequate temperatures for pathogen destruction.<sup>39</sup> A study conducted in 1955 at Michigan State University, however, indicated that optimal decomposition occurs at an even lower temperature of 45°C (113°F).<sup>40</sup> Another researcher asserts that maximum biodegradation occurs at 45-55°C (113-131°F), while maximum microbial diversity requires a temperature range of 35-45°C (95-113°F).<sup>41</sup> Apparently, there is still some degree of flexibility in these estimates, as the science of “compost microhusbandry” is not an utterly precise one at this time. Control of excessive heat, however, is probably not a concern for the backyard composter.

Some thermophilic actinomycetes, as well as mesophilic bacteria, produce antibiotics that display considerable potency toward other bacteria and yet exhibit low toxicity when tested on mice. Up to one half of thermophilic strains can produce antimicrobial compounds, some of which have been shown to be effective against *E. coli* and *Salmonella*. One thermophilic strain with an optimum growth temperature of 50°C produces a substance that “significantly aided the healing of infected surface wounds in clinical tests on human subjects. The product(s) also stimulated growth of a variety of cell types, including various animal and plant tissue cultures and unicellular algae.”<sup>42</sup> The production of antibiotics by compost microorganisms theoretically assists in the destruction of human pathogens that may have existed in the organic material before composting.

Even if every speck of the composting material is not subjected to the high internal temperatures of the compost pile, the process

of thermophilic composting nevertheless contributes immensely toward the creation of a sanitary organic material. Or, in the words of one group of composting professionals, “*The high temperatures achieved during composting, assisted by the competition and antagonism among the microorganisms [i.e., biodiversity], considerably reduce the number of plant and animal pathogens. While some resistant pathogenic organisms may survive and others may persist in cooler sections of the pile, the disease risk is, nevertheless, greatly reduced.*”<sup>43</sup>

If a backyard composter has any doubt or concern about the existence of pathogenic organisms in his or her humanure compost, s/he can use the compost for horticultural purposes rather than for food purposes. Humanure compost can grow an amazing batch of berries, flowers, bushes, or trees. Furthermore, lingering pathogens continue to die after the compost has been applied to the soil, which is not surprising since human pathogens prefer the warm and moist environment of the human body. As the World Bank researchers put it, “*even pathogens remaining in compost seem to disappear rapidly in the soil.*” [Night Soil Composting, 1981] Finally, compost can be tested for pathogens by compost testing labs. Such labs are listed in Chapter Six.

Some say that a few pathogens in soil or compost are OK. “*Another point most folks don’t realize is that no compost and no soil are completely pathogen free. You really don’t want it to be completely pathogen free, because you always want the defense mechanism to have something to practice on. So a small number of disease-causing organisms is desirable. But that’s it.*”<sup>44</sup> Pathogens are said to have “minimum infective doses,” which vary widely from one type of pathogen to another, meaning that a number of pathogens are necessary in order to initiate an infection. The idea, therefore, that compost must be sterile is incorrect. It must be *sanitary*, which means it must have a greatly weakened, reduced or destroyed pathogen population.

In reality, the average backyard composter knows whether his or her family is healthy or not. Healthy families have little to be concerned about and can feel confident that their thermophilic compost can be safely returned to the soil, provided the simple instructions in this book are followed regarding compost temperatures and retention times, as discussed in Chapter Seven. On the other hand, there will always be those people who are fecophobic, and who will never be convinced that humanure compost is safe. These people are not likely to compost their humanure anyway, so who cares?

## COMPOST MYTHS

### TO TURN OR NOT TO TURN: THAT IS THE QUESTION

What is one of the first things to come to mind when one thinks of compost? Turning the pile. *Turn, turn, turn*, has become the mantra of composters worldwide. Early researchers who wrote seminal works in the composting field, such as Gotaas, Rodale, and many others, emphasize turning compost piles, almost obsessively so.

Much of compost's current popularity in the West can be attributed to the work of Sir Albert Howard, who wrote *An Agricultural Testament* in 1943 and several other works on aspects of what has now become known as organic agriculture. Howard's discussions of composting techniques focus on the Indore process of composting, a process developed in Indore, India, between the years of 1924 and 1931. The Indore process was first described in detail in Howard's 1931 work, co-authored with Y. D. Wad, *The Waste Products of Agriculture*. The two main principles underlying the Indore composting process include: 1) mixing animal and vegetable refuse with a neutralizing base, such as agricultural lime; and 2) managing the compost pile by physically turning it. The Indore process subsequently became adopted and espoused by composting enthusiasts in the West, and today one still commonly sees people turning and liming compost piles. For example, Robert Rodale wrote in the February, 1972, issue of *Organic Gardening* concerning composting humanure, "We recommend turning the pile at least three times in the first few months, and then once every three months thereafter for a year."

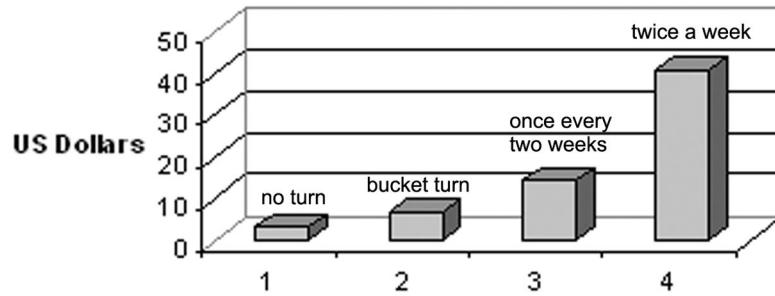
A large industry has emerged from this philosophy, one which manufactures expensive compost turning equipment, and a lot of money, energy and expense go into making sure compost is turned regularly. For some compost professionals, the suggestion that compost doesn't need to be turned at all is utter blasphemy. Of course you have to turn it — it's a compost pile, for heaven's sake.

Or do you? Well, in fact, *no*, you don't, especially if you're a backyard composter, and not even if you're a large scale composter. The perceived need to turn compost is one of the myths of composting.

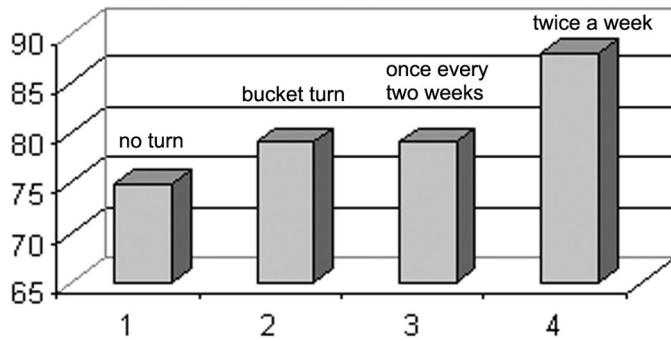
Turning compost potentially serves four basic purposes. First, turning is supposed to add oxygen to the compost pile, which is supposed to be good for the aerobic microorganisms. We are warned that if we do not turn our compost, it will become anaerobic and smell

Figure 3.6

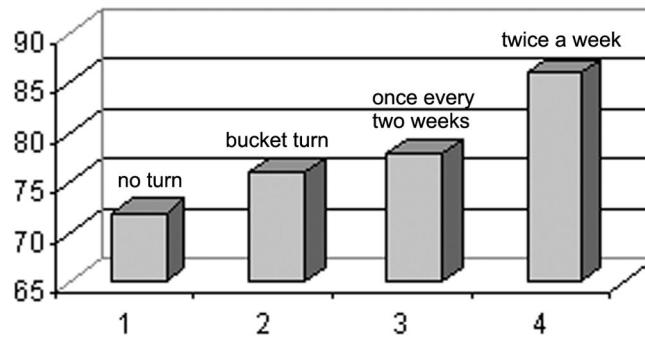
### Compost Turning Costs



### Organic Matter Loss Due to Turning (%)



### Nitrogen Loss Due To Turning (%)



Source: Brinton, William F. Jr. (date unknown). Sustainability of Modern Composting - Intensification Versus Cost and Quality. Woods End Institute, PO Box 297, Mt. Vernon, Maine 04352 USA.

bad, attract rats and flies, and make us into social pariahs in our neighborhoods. Second, turning the compost ensures that all parts of the pile are subjected to the high internal heat, thereby ensuring total pathogen death and yielding a hygienically safe, finished compost. Third, the more we turn the compost, the more it becomes chopped and mixed, and the better it looks when finished, rendering it more marketable. Fourth, frequent turning can speed up the composting process.

Since backyard composters don't actually market their compost, usually don't care if it's finely granulated or somewhat coarse, and usually have no good reason to be in a hurry, we can eliminate the last two reasons for turning compost right off the bat. Let's look at the first two.

Aeration is necessary for aerobic compost, and there are numerous ways to aerate a compost pile. One is to force air into or through the pile using fans, which is common at large-scale composting operations where air is sucked from under the compost piles and out through a biofilter. The suction causes air to seep into the organic mass through the top, thereby keeping it aerated. An accelerated flow of air through a compost mass can cause it to heat up quite drastically; then the air flow also becomes a method for trying to reduce the temperature of the compost because the exhaust air draws quite a bit of heat away from the compost pile. Such mechanical aeration is never a need of the backyard composter and is limited to large scale composting operations where the piles are so big they can smother themselves if not subjected to forced aeration.

Aeration can also be achieved by poking holes in the compost, driving pipes into it and generally impaling it. This seems to be popular among some backyard composters. A third way is to physically turn the pile. A fourth, largely ignored way, however, is to build the pile so that tiny interstitial air spaces are trapped in the compost. This is done by using coarse materials in the compost, such as hay, straw, weeds, and the like. When a compost pile is properly constructed, no additional aeration will be needed. Even the organic gardening pros admit that, “*good compost can be made without turning by hand if the materials are carefully layered in the heap which is well-ventilated and has the right moisture content.*”<sup>45</sup>

This is especially true for “continuous compost,” which is different from “batch compost.” Batch compost is made from a batch of material that is composted all at once. This is what commercial composters do — they get a dump truck load of garbage or sewage sludge

from the municipality and compost it in one big pile. Backyard composters, especially humanure composters, produce organic residues daily, a little at a time and rarely, if ever, in big batches. Therefore, continuous composters add material continuously to a compost pile usually by putting the fresh material on the top. This causes the thermophilic activity to be in the upper part of the pile while the thermophilically “spent” part of the compost sinks lower and lower, to be worked on by fungi, actinomycetes, earthworms and lots of other things. Turning continuous compost dilutes the thermophilic layer with the spent layers and can quite abruptly stop all thermophilic activity.

Researchers have measured oxygen levels in large-scale windrow composting operations (a windrow is a long, narrow pile of compost). One reported, “*Oxygen concentration measurements taken within the windrows during the most active stage of the composting process, showed that within fifteen minutes after turning the windrow — supposedly aerating it — the oxygen content was already depleted.*”<sup>46</sup> Other researchers compared the oxygen levels of large, turned and unturned batch compost piles, and have come to the conclusion that compost piles are largely self-aerated. “*The effect of pile turning was to refresh oxygen content, on average for [only] 1.5 hours (above the 10% level), after which it dropped to less than 5% and in most cases to 2% during the active phase of composting . . . Even with no turning, all piles eventually resolve their oxygen tension as maturity approaches, indicating that self-aeration alone can adequately furnish the composting process . . . In other words, turning the piles has a temporal but little sustained influence on oxygen levels.*” These trials compared compost that was not turned, bucket turned, turned once every two weeks and turned twice a week.<sup>47</sup>

Interestingly enough, the same trials indicated that bacterial pathogens were destroyed whether the piles were turned or unturned, stating that there was no evidence that bacterial populations were influenced by turning schemes. There were no surviving *E. coli* or *Salmonella* strains, indicating that there were “*no statistically significant effects attributable to turning.*” Unturned piles can benefit by the addition of extra coarse materials such as hay or straw, which trap extra air in the organic material and make additional aeration unnecessary. Furthermore, unturned compost piles can be covered with a thick insulating layer of organic material, such as hay, straw or even finished compost, which can allow the temperatures on the outer edges of the pile to grow warm enough for pathogen destruction.

Not only can turning compost piles be an unnecessary expen-

diture of energy, but the above trials also showed that when batch compost piles are turned frequently, some other disadvantageous effects can result (see Figure 3.6 on page 49). For example, the more frequently compost piles are turned, the more agricultural nutrients they lose. When the finished compost was analyzed for organic matter and nitrogen loss, the unturned compost showed the least loss. The more frequently the compost was turned, the greater was the loss of both nitrogen *and* organic matter. Also, the more the compost was turned, the more it cost. The unturned compost cost \$3.05 per wet ton, while the compost turned twice a week cost \$41.23 per wet ton, a 1,351% increase. The researchers concluded that “*Composting methods that require intensification [frequent turning] are a curious result of modern popularity and technological development of composting as particularly evidenced in popular trade journals. They do not appear to be scientifically supportable based on these studies . . . By carefully managing composting to achieve proper mixes and limited turning, the ideal of a quality product at low economic burden can be achieved.*”<sup>48</sup>

When large piles of municipal compost are turned, they give off emissions of such things as *Aspergillus fumigatus* fungi which can cause health problems in people. Aerosol concentrations from static (unturned) piles are relatively small when compared to mechanically turned compost. Measurements thirty meters downwind from static piles showed that aerosol concentrations of *A. fumigatus* were not significantly above background levels, and were “33 to 1800 times less” than those from piles that were being moved.<sup>49</sup>

Finally, turning compost piles in cold climates can cause them to lose too much heat. It is recommended that cold climate composters turn less frequently, if at all.<sup>50</sup>

#### DO YOU NEED TO INOCULATE YOUR COMPOST PILE?

No. This is perhaps one of the most astonishing aspects of composting.

In October of 1998, I took a trip to Nova Scotia, Canada, to observe the municipal composting operations there. The Province had legislated that as of November 30, 1998, no organic materials could be disposed of in landfills. By the end of October, with the “ban date” approaching, virtually all municipal organic garbage was being collected and transported instead to composting facilities, where it was effectively being recycled and converted into humus. The municipal garbage trucks would simply back into the compost facility

building (the composting was done indoors), and then dump the garbage on the floor. The material consisted of the normal household and restaurant food materials such as banana peels, coffee grounds, bones, meat, spoiled milk and paper products such as cereal boxes. The occasional clueless person would contribute a toaster oven, but these were sorted out. The organic material was then checked for other contaminants such as bottles and cans, run through a grinder, and finally shoved into a concrete compost bin. Within 24-48 hours, the temperature of the material would climb to 70°C (158°F). No inoculants were required. Incredibly, the thermophilic bacteria were already there, waiting in the garbage for this moment to arrive.

Researchers have composted materials with and without inocula and found that, “*although rich in bacteria, none of the inocula accelerated the composting process or improved the final product . . . The failure of the inocula to alter the composting cycle is due to the adequacy of the indigenous microbial population already present and to the nature of the process itself . . . The success of composting operations without the use of special inocula in the Netherlands, New Zealand, South Africa, India, China, the U.S.A, and a great many other places, is convincing evidence that inocula and other additives are not essential in the composting of [organic] materials.*”<sup>51</sup> Others state, “*No data in the literature indicate that the addition of inoculants, microbes, or enzymes accelerate the compost process.*”<sup>52</sup>

#### LIME

It is not necessary to put lime (ground agricultural limestone) on your compost pile. The belief that compost piles should be limed is a common misconception. Nor are other mineral additives needed on your compost. If your soil needs lime, put the lime on your soil, not your compost. Bacteria don’t digest limestone; in fact lime is used to *kill* microorganisms in sewage sludge — it’s called *lime-stabilized* sludge.

Aged compost is not acidic, even with the use of sawdust. The pH of finished compost should slightly exceed 7 (neutral). What is pH? It’s a measure of acidity and alkalinity which ranges from 1-14. Neutral is 7. Below seven is acidic; above seven is basic or alkaline. If the pH is too acidic or too alkaline, bacterial activity will be hindered or stopped completely. Lime and wood ashes raise the pH, but wood ashes should also go straight on the soil. The compost pile doesn’t need them. It may seem logical that one should put into one’s com-

post pile whatever one also wants to put into one's garden soil, as the compost will end up in the garden eventually, but that's not the reality of the situation. *What one should put into one's compost is what the microorganisms in the compost want or need, not what the garden soil wants or needs.*

Sir Albert Howard, one of the most well-known proponents of composting, as well as J. I. Rodale, another prominent organic agriculturist, have recommended adding lime to compost piles.<sup>53</sup> They seemed to base their reasoning on the belief that the compost will become acidic during the composting process, and therefore the acidity must be neutralized by adding lime to the pile while it's composting. It may well be that some compost becomes acidic during the process of decomposition, however, it seems to neutralize itself if left alone, yielding a neutral, or slightly alkaline end product. Therefore, it is recommended that you test your *finished* compost for pH before deciding that you need to neutralize any acids.

I find it perplexing that the author who recommended liming compost piles in one book, states in another, “*The control of pH in composting is seldom a problem requiring attention if the material is kept aerobic... the addition of alkaline material is rarely necessary in aerobic decomposition and, in fact, may do more harm than good because the loss of nitrogen by the evolution of ammonia as a gas will be greater at the higher pH.*”<sup>54</sup> In other words, don't assume that you should lime your compost. Only do so if your finished compost is consistently acidic, which would be highly unlikely. Get a soil pH test kit and check it out. Researchers have indicated that maximum thermophilic composting occurs at a pH range between 7.5 to 8.5, which is slightly alkaline.<sup>55</sup> But don't be surprised if your compost is slightly acidic at the start of the process. It should turn neutral or slightly alkaline and remain so when completely cured.

Scientists who were studying various commercial fertilizers found that agricultural plots to which composted sewage sludge had been added made better use of lime than plots without composted sludge. The lime in the composted plots changed the pH deeper in the soil indicating that organic matter assists calcium movement through the soil “*better than anything else,*” according to Cecil Tester, Ph.D., research chemist at USDA's Microbial Systems Lab in Beltsville, MD.<sup>56</sup> The implications are that compost should be added to the soil when lime is added to the soil.

Perhaps Gotaas sums it up best, “*Some compost operators have suggested the addition of lime to improve composting. This should be done*

*only under rare circumstances such as when the raw material to be composted has a high acidity due to acid industrial wastes or contains materials that give rise to highly acid conditions during composting.”*<sup>57</sup>

#### WHAT NOT TO COMPOST? YOU CAN COMPOST ALMOST ANYTHING.

I get a bit perturbed when I see compost educators telling their students that there is a long list of things “*not* to be composted!” This prohibition is always presented in such an authoritative and serious manner that novice composters begin trembling in their boots at the thought of composting any of the banned materials. I can imagine naive composters armed with this misinformation carefully segregating their food scraps so that, God forbid, the wrong materials don’t end up in the compost pile. Those “banned” materials include meat, fish, milk, butter, cheese and other dairy products, bones, lard, mayonnaise, oils, peanut butter, salad dressing, sour cream, weeds with seeds, diseased plants, citrus peels, rhubarb leaves, crab grass, pet manures, and perhaps worst of all — human manure. Presumably, one must segregate half-eaten peanut butter sandwiches from the compost bucket, or any sandwich with mayonnaise or cheese, or any left-over salad with salad dressing, or spoiled milk, or orange peels, all of which must go to a landfill and be buried under tons of dirt instead of being composted. Luckily, I was never exposed to such instructions, and my family has composted *every bit* of food scrap it has produced, including meat, bones, butter, oils, fat, lard, citrus peels, mayonnaise and everything else on the list. We’ve done this in our backyard for 26 years with *never* a problem. Why would it work for us and not for anyone else? The answer, in a word, if I may hazard a guess, is *humanure*, another forbidden compost material.

When compost heats up, much of the organic material is quickly degraded. This holds true for oils and fats, or in the words of scientists, “*Based on evidence on the composting of grease trap wastes, lipids [fats] can be utilized rapidly by bacteria, including actinomycetes, under thermophilic conditions.*”<sup>58</sup> The problem with the materials on the “banned” list is that they may require thermophilic composting conditions for best results. Otherwise, they can just sit in the compost pile and only very slowly decompose. In the meantime, they can look very attractive to the wandering dog, cat, raccoon, or rat. Ironically, when the forbidden materials, including humanure, are combined with other compost ingredients, thermophilic conditions will prevail. When humanure and the other controversial organic materials are

segregated from compost, thermophilic conditions may not occur at all. This is a situation that is probably quite common in most backyard compost piles. The solution is not to segregate materials from the pile, but to add nitrogen and moisture, as are commonly found in manure.

As such, compost educators would provide a better service to their students if they told them the truth: almost any organic material will compost — rather than give them the false impression that some common food materials will not. Granted, some things do not compost very well. Bones are one of them, but they do no harm in a compost pile.

Nevertheless, toxic chemicals *should* be kept out of the backyard compost pile. Such chemicals are found, for example, in some “pressure treated” lumber that is saturated with cancer-causing chemicals such as chromated copper arsenate. What not to compost: sawdust from CCA pressure treated lumber, which is, unfortunately, a toxic material that has been readily available to the average gardener for too many years (but now largely banned by the EPA).

## COMPOST MIRACLES

### COMPOST CAN DEGRADE TOXIC CHEMICALS

Compost microorganisms not only convert organic material into humus, but they also degrade toxic chemicals into simpler, benign, organic molecules. These chemicals include gasoline, diesel fuel, jet fuel, oil, grease, wood preservatives, PCBs, coal gasification wastes, refinery wastes, insecticides, herbicides, TNT, and other explosives.<sup>59</sup>

In one experiment in which compost piles were laced with insecticides and herbicides, the insecticide (carbofuran) was completely degraded, and the herbicide (triazine) was 98.6% degraded after 50 days of composting. Soil contaminated with diesel fuel and gasoline was composted, and after 70 days in the compost pile, the total petroleum hydrocarbons were reduced approximately 93%.<sup>60</sup> Soil contaminated with Dicamba herbicide at a level of 3,000 parts per million showed no detectable levels of the toxic contaminant after only 50 days of composting. In the absence of composting, this biodegradation process normally takes years.

Compost seems to strongly bind metals and prevent their uptake by both plants and animals, thereby preventing transfer of

metals from contaminated soil into the food chain.<sup>62</sup> One researcher fed lead-contaminated soil to rats, some with compost added, and some without. The soil to which compost had been added produced no toxic effects, whereas the soil without compost did produce some toxic effects.<sup>61</sup> Plants grown in lead contaminated soil with ten percent compost showed a reduction in lead uptake of 82.6%, compared to plants grown in soil with no compost.<sup>63</sup>

Fungi in compost produce a substance that breaks down petroleum, thereby making it available as food for bacteria.<sup>64</sup> One man who composted a batch of sawdust contaminated with diesel oil said, “*We did tests on the compost, and we couldn’t even find the oil!*” The compost had apparently “eaten” it all.<sup>65</sup> Fungi also produce enzymes that can be used to replace chlorine in the paper-making process. Researchers in Ireland have discovered that fungi gathered from compost heaps can provide a cheap and organic alternative to toxic chemicals.<sup>66</sup>

Compost has been used in recent years to degrade other toxic chemicals as well. For example, chlorophenol contaminated soil was composted with peat, sawdust and other organic matter and after 25 months, the chlorophenol was reduced in concentration by 98.73%. Freon contamination was reduced by 94%, PCPs by up to 98%, and TCE by 89-99% in other compost trials.<sup>67</sup> Some of this degradation is due to the efforts of fungi at lower (mesophilic) temperatures.<sup>68</sup>

Some bacteria even have an appetite for uranium. Derek Lovley, a microbiologist, has been working with a strain of bacteria that normally lives 650 feet under the Earth’s surface. These microorganisms will eat, then excrete, uranium. The chemically altered uranium excreta becomes water insoluble as a result of the microbial digestion process, and can consequently be removed from the water it was contaminating.<sup>69</sup>

An Austrian farmer claims that the microorganisms he introduces into his fields have prevented his crops from being contaminated by the radiation from Chernobyl, the ill-fated Russian nuclear power plant, which contaminated his neighbor’s fields. Sigfried Lubke sprays his green manure crops with compost-type microorganisms just before plowing them under. This practice has produced a soil rich in humus and teeming with microscopic life. After the Chernobyl disaster, crops from fields in Lubke’s farming area were banned from sale due to high amounts of radioactive cesium contamination. However, when officials tested Lubke’s crops, no trace of cesium could be found. The officials made repeated tests because

they couldn't believe that one farm showed no radioactive contamination while the surrounding farms did. Lubke surmises that the humus just "ate up" the cesium.<sup>70</sup>

Compost is also able to decontaminate soil polluted with TNT from munitions plants. The microorganisms in the compost digest the hydrocarbons in TNT and convert them into carbon dioxide, water and simple organic molecules. The method of choice for eliminating contaminated soil has thus far been incineration. However, composting costs far less, and yields a material that is valuable (compost), as opposed to incineration, which yields an ash that must itself be disposed of as toxic waste. When the Umatilla Army Depot in Hermiston, Oregon, a Superfund site, composted 15,000 tons of contaminated soil instead of incinerating it, it saved approximately \$2.6 million. Although the Umatilla soil was heavily contaminated with TNT and RDX (Royal Demolition Explosives), no explosives could be detected after composting and the soil was restored to "*a better condition than before it was contaminated.*"<sup>71</sup> Similar results have been obtained at Seymour Johnson Air Force Base in North Carolina, the Louisiana Army Ammunition Plant, the U.S. Naval Submarine Base in Bangor, Washington, Fort Riley in Kansas, and the Hawthorne Army Depot in Nevada.<sup>72</sup>

The U.S. Army Corps of Engineers estimates that we would save hundreds of millions of dollars if composting, instead of incineration, were used to clean up the remaining U.S. munitions sites. The ability of compost to bioremediate toxic chemicals is particularly meaningful when one considers that in the U.S. there are currently 1.5 million underground storage tanks leaking a wide variety of materials into soil, as well as 25,000 Department of Defense sites in need of remediation. In fact, it is estimated that the remediation costs for America's most polluted sites using standard technology may reach \$750 billion, while in Europe the costs could reach \$300 to \$400 billion.

As promising as compost bioremediation appears, however, it cannot heal all wounds. Heavily chlorinated chemicals show considerable resistance to microbiological biodegradability. Apparently, there are even some things a fungus will spit out.<sup>73</sup> On the other hand, some success has been shown in the bioremediation of PCBs (polychlorinated biphenyls) in composting trials conducted by Michigan State University researchers in 1996. In the best case, PCB loss was in the 40% range. Despite the chlorinated nature of the PCBs, researchers still managed to get quite a few microorganisms to choke

the stuff down.<sup>74</sup>

Then there's the villain *Clopyralid* (3,6-dichloropicolinic acid), an herbicide manufactured by Dow AgroSciences that has contaminated vast amounts of commercial compost in the early 21st century. It is commonly sold under the brand names Transline™, Stinger™, and Confront™. This chemical has the unusual effect of passing through the composting process and leaving residues that are still chemically active. The result is contaminated compost that can kill some of the plants grown in it. Even a compost pile can have a bad day.<sup>xx</sup>

#### COMPOST CAN FILTER POLLUTED AIR AND WATER

Compost can control odors. Biological filtration systems, called "biofilters," are used at large-scale composting facilities where exhaust gases are filtered for odor control. The biofilters are composed of layers of organic material such as wood chips, peat, soil, and compost through which the air is drawn in order to remove any contaminants. The microorganisms in the organic material eat the contaminants and convert them into carbon dioxide and water (see Figure 3.8).

In Rockland County, New York, one such biofiltration system can process 82,000 cubic feet of air a minute and guarantee no detectable odor at or beyond the site property line. Another facility in Portland, Oregon, uses biofilters to remediate aerosol cans prior to disposal. After such remediation, the cans are no longer considered hazardous and can be disposed of more readily. In this case, a \$47,000 savings in hazardous waste disposal costs was realized over a period of 18 months. Vapor Phase Biofilters can maintain a consistent Volatile Organic Compound removal efficiency of 99.6%, which isn't bad for a bunch of microorganisms.<sup>75</sup> After a year or two, the biofilter is recharged with new organic material and the old stuff is simply composted or applied to land.

Compost is also now used to filter stormwater runoff (see Figure 3.8). Compost Stormwater Filters use compost to filter out heavy metals, oil, grease, pesticides, sediment, and fertilizers from stormwater runoff. Such filters can remove over 90% of all solids, 82% to 98% of heavy metals and 85% of oil and grease, while filtering up to eight cubic feet per second. These Compost Stormwater Filters prevent stormwater contamination from polluting our natural waterways.<sup>76</sup>

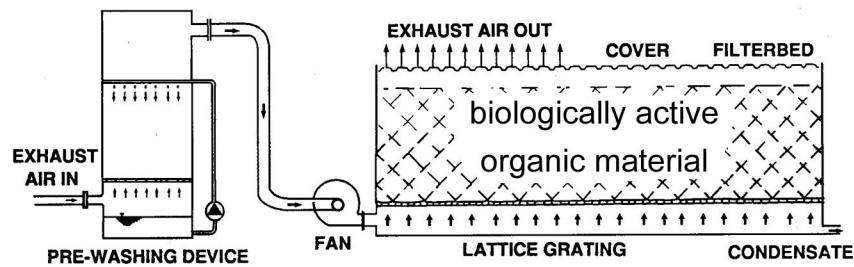
## COMPOST DEFENDS PLANTS FROM DISEASES

The composting process can destroy many plant pathogens. Because of this, diseased plant material should be thermophilically composted rather than returned to the land where reinoculation of the disease could occur. The beneficial microorganisms in thermophilic compost directly compete with, inhibit, or kill organisms that cause diseases in plants. Plant pathogens are also eaten by microarthropods, such as mites and springtails, which are found in compost.<sup>77</sup>

Compost microorganisms can produce antibiotics which suppress plant diseases. Compost added to soil can also activate disease resistance genes in plants, preparing them for a better defense against plant pathogens. Systemic Acquired Resistance caused by compost in soils allows plants to resist the effects of diseases such as *Anthracnose* and *Pythium* root rot in cucumbers. Experiments have shown that when only some of the roots of a plant are in compost-amended soil, while the other roots are in diseased soil, the entire plant can still acquire resistance to the disease.<sup>78</sup> Researchers have shown that compost combats chili wilt (*Phytophthora*) in test plots of chili peppers, and suppresses ashy stem blight in beans, *Rhizoctonia* root rot in black-eyed peas,<sup>79</sup> *Fusarium oxysporum* in potted plants, and gummy stem blight and damping-off diseases in squash.<sup>80</sup> It is now recognized that the control of root rots with composts can be as effective as synthetic fungicides such as methyl bromide. Only a small percentage of compost microorganisms can, however, induce disease resistance in plants, which again emphasizes the importance of biodiversity in compost.

Studies by researcher Harry Hoitink indicated that compost inhibited the growth of disease-causing microorganisms in greenhouses by adding beneficial microorganisms to the soil. In 1987, he and a team of scientists took out a patent for compost that could reduce or suppress plant diseases caused by three deadly microorganisms: *Phytophthora*, *Pythium* and *Fusarium*. Growers who used this compost in their planting soil reduced their crop losses from 25-75% to 1% without applying fungicides. The studies suggested that sterile soils could provide optimum breeding conditions for plant disease microorganisms, while a rich diversity of microorganisms in soil, such as that found in compost, would render the soil unfit for the proliferation of disease organisms.<sup>81</sup>

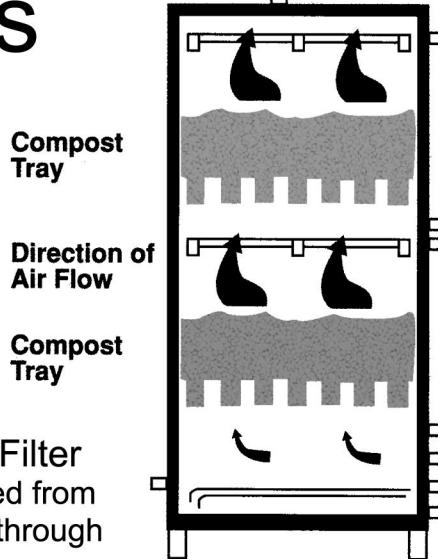
In fact, compost tea has also been demonstrated to have dis-



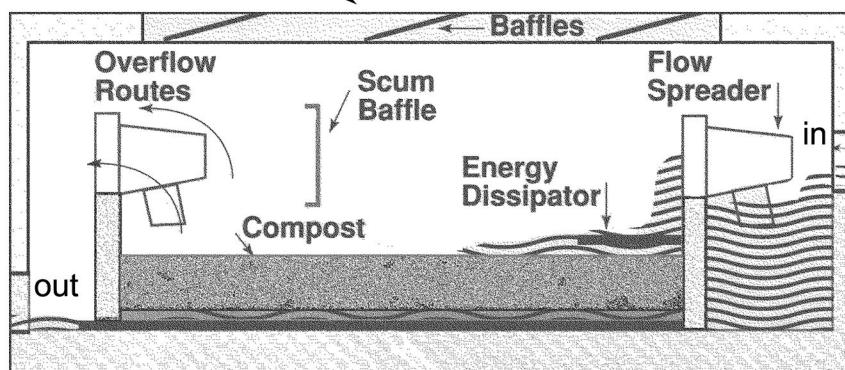
# Biofilters

Figure 3.8

Vapor Phase  
Compost  
Biofilter



**Compost Stormwater Filter**  
Contaminants are removed from stormwater when filtered through layers of compost.



Source: US EPA

ease-reducing properties in plants. Compost tea is made by soaking mature, but not overly mature compost in water for three to twelve days. The tea is then filtered and sprayed on plants undiluted, thereby coating the leaves with live bacteria colonies. When sprayed on red pine seedlings, for example, blight was significantly reduced in severity.<sup>82</sup> Powdery mildew (*Uncinula necator*) on grapes was very successfully suppressed by compost tea made from cattle manure compost.<sup>83</sup> “*Compost teas can be sprayed on crops to coat leaf surfaces and actually occupy the infection sites that could be colonized by disease pathogens,*” states one researcher, who adds, “*There are a limited number of places on a plant that a disease pathogen can infect, and if those spaces are occupied by beneficial bacteria and fungi, the crop will be resistant to infection.*”<sup>84</sup>

Besides helping to control soil diseases, compost attracts earthworms, aids plants in producing growth stimulators, and helps control parasitic nematodes.<sup>85</sup> Compost “biopesticides” are now becoming increasingly effective alternatives to chemical bug killers. These “designer composts” are made by adding certain pest-fighting microorganisms to compost, yielding a compost with a specific pest-killing capacity. Biopesticides must be registered with the U.S. EPA and undergo the same testing as chemical pesticides to determine their effectiveness and degree of public safety.<sup>86</sup>

Finally, composting destroys weed seeds. Researchers observed that after three days in compost at 55°C (131°F), all of the seeds of the eight weed species studied were dead.<sup>87</sup>

#### COMPOST CAN RECYCLE THE DEAD

Dead animals of all species and sizes can be recycled by composting. Of the 7.3 billion chickens, ducks and turkeys raised in the U.S. each year, about 37 million die from disease and other natural causes before they’re marketed.<sup>88</sup> The dead birds can simply be composted. The composting process not only converts the carcasses to humus which can be returned directly to the farmer’s fields, but it also destroys the pathogens and parasites that may have killed the birds in the first place. It is preferable to compost diseased animals on the farm where they originated rather than transport them elsewhere and risk spreading the disease. A temperature of 55°C maintained for at least three consecutive days maximizes pathogen destruction.

Composting is considered a simple, economic, environmentally sound and effective method of managing animal mortalities.

Carcasses are buried in a compost pile. The composting process ranges from several days for small birds to six or more months for mature cattle. Generally, the total time required ranges from two to twelve months depending on the size of the animal and other factors such as ambient air temperature. The rotting carcasses are never buried in the ground where they may pollute groundwater, as is typical when composting is not used. Animal mortality recycling can be accomplished without odors, flies or scavenging birds or animals.

Such practices were originally developed to recycle dead chickens, but the animal carcasses that are now composted include full-grown pigs, cattle and horses, as well as fish, sheep, calves, and other animals. The biological process of composting dead animals is identical to the process of composting any organic material. The carcasses provide nitrogen and moisture, while materials such as sawdust, straw, corn stalks and paper provide carbon and bulk for air impregnation. The composting can be done in temporary three-sided bins made of straw or hay bales. A layer of absorbent organic material is used to cover the bottom of the bin, acting as a sponge for excess liquids. Large animals are placed back down in the compost, with their abdominal and thoracic cavities opened, and covered with organic material. Sawmill sawdust has been shown to be one of the most effective organic materials with which to compost dead animals. After filling the bin with properly prepared animal mortalities, the top is covered with clean organic material that acts as a biofilter for odor control. Although large bones may remain after the composting process, they are easily broken down when applied to the soil.<sup>89</sup>

Backyard composters can also make use of this technique. When a small animal has died and the carcass needs to be recycled, simply dig a hole in the top center of the compost pile, deposit the carcass, cover it with the compost, then cover it all with a clean layer of organic material such as straw, weeds or hay. You will never see the carcass again. This is also a good way to deal with fish, meat scraps, milk products and other organic materials that may otherwise be attractive to nuisance animals.

We keep some ducks and chickens on our homestead, and occasionally one of them dies. A little poking around in the compost pile to create a depression in the top, and a plop of the carcass into the hole, and another creature is on the road to reincarnation. We've also used this technique regularly for recycling other smaller animal carcasses such as mice, baby chicks and baby rabbits. After we collect earthworms from our compost pile to go fishing at the local pond, we

filet the catch and put the filets in the freezer for winter consumption. The fish remains go straight into the compost, buried in the same manner as any other animal mortality. We have several outdoor cats, and they wouldn't be caught dead digging around in humanure compost looking for a bite to eat. Nor would our dog — and dogs will eat anything, but not when buried in thermophilic compost.

On the other hand, some dogs *may* try to get into your compost pile. Make sure your compost bin has dog proof side walls and then simply throw a piece of stiff wire fencing over the top of the compost. That's all it takes. Until dogs learn how to use wire cutters, your compost will be safe.

#### COMPOST RECYCLES PET MANURES

Can you use dog manure in your compost? Good question. I can honestly say that I've never tried it, as I do not have a source of dog manure for experimentation (my dog is a free-roaming outdoor dog). Numerous people have written to ask whether pet manures can go into their household compost piles and I have responded that I don't know from experience. So I've recommended that pet manures be collected in their own separate little compost bins with cover materials such as hay, grass clippings, leaves, weeds or straw, and perhaps occasionally watered a bit to provide moisture. A double bin system will allow the manures to be collected for quite some time in one bin, then aged for quite some time while the second bin is being filled. What size bin? About the size of a large garbage can, although a larger mass may be necessary in order to spark a thermophilic reaction.

On the other hand, this may be entirely too much bother for most pet owners who are also composters, and you may just want to put pet and human manures into one compost bin. This would certainly be the simpler method. The idea of composting dog manure has been endorsed by J. I. Rodale in the Encyclopedia of Organic Gardening. He states, "*Dog manure can be used in the compost heap; in fact it is the richest in phosphorous if the dogs are fed with proper care and given their share of bones.*" He advises the use of cover materials similar to the ones I mentioned above, and recommends that the compost bin be made dog-proof, which can be done with straw bales, chicken wire, boards or fencing.

## ONE WAY TO RECYCLE JUNK MAIL

Composting is a solution for junk mail, too. A pilot composting project was started in Dallas-Ft. Worth, Texas, where 800 tons of undeliverable bulk mail are generated annually. The mail was ground in a tub grinder, covered with wood chips so it wouldn't blow away, then mixed with zoo manure, sheep entrails and discarded fruits and vegetables. The entire works was kept moist and thoroughly mixed. The result — a finished compost "*as good as any other compost commercially available.*" It grew a nice bunch of tomatoes, too.<sup>90</sup>

What about newspapers in backyard compost? Yes, newspaper will compost, but there are some concerns about newsprint. For one, the glossy pages are covered with a clay that retards composting. For another, the inks can be petroleum-based solvents or oils with pigments containing toxic substances such as chromium, lead and cadmium in both black and colored inks. Pigment for newspaper ink still comes from benzene, toluene, naphthalene and other benzene ring hydrocarbons which may be quite harmful to human health if accumulated in the food chain. Fortunately, quite a few newspapers today are using soy-based inks instead of petroleum-based inks. If you really want to know about the type of ink in your newspaper, call your newspaper office and ask them. Otherwise, keep the glossy paper or colored pages in your compost to a minimum. Remember, ideally, compost is being made to produce human food. One should try to keep the contaminants out of it, if possible.<sup>91</sup>

Wood's End Laboratory in Maine did some research on composting ground-up telephone books and newsprint which had been used as bedding for dairy cattle. The ink in the paper contained common cancer-causing chemicals, but after composting it with dairy cow manure, the dangerous chemicals were reduced by 98%.<sup>92</sup> So it appears that if you're using shredded newspaper for bedding under livestock, you *should* compost it, if for no other reason than to eliminate some of the toxic elements from the newsprint. It'll probably make acceptable compost too, especially if layered with garbage, manure and other organic materials.

What about things like sanitary napkins and disposable diapers? Sure, they'll compost, but they'll leave strips of plastic throughout your finished compost which are quite unsightly. Of course, that's OK if you don't mind picking the strips of plastic out of your compost. Otherwise, use cloth diapers and washable cloth menstrual pads instead.

Toilet paper composts, too. So do the cardboard tubes in the center of the rolls. Unbleached, recycled toilet paper is ideal. Or you can use the old-fashioned toilet paper, otherwise known as corncobs. Popcorn cobs work best, they're softer. Corncobs don't compost very readily though, so you have a good excuse not to use them. There are other things that don't compost well: eggshells, bones, hair and woody stems, to name a few.

Compost professionals have almost fanatically seized upon the idea that wood chips are good for making compost. Nowadays, when novice composters want to begin making compost, the first thing they want to know is where they can get wood chips. In fact, wood chips do *not* compost very well at all, unless ground into fine particles, as in sawdust. Even compost professionals admit that they have to screen out their wood chips *after* the compost is finished because they didn't decompose. They insist on using them anyway, because they break up the compost consistency and maintain air spaces in their large masses of organic material. However, a home composter should avoid wood chips and use other bulking materials that degrade more quickly, such as hay, straw, sawdust and weeds.

Finally, never put woody-stemmed plants, such as tree saplings, on your compost pile. I hired a young lad to clear some brush for me one summer and he innocently put the small saplings on my compost pile without me knowing it. Later, I found them networked through the pile like iron reinforcing rods. I'll bet the lad's ears were itching that day — I sure had some nasty things to say about him. Fortunately, only Gomer, the compost pile, heard me.

## VERMICOMPOSTING

Vermicomposting, or worm composting, involves the use of redworms such as *Eisenia fetida* or *Lumbricus rubellus* to consume organic material either in specially designed worm boxes, or in large-scale, outdoor compost piles. Redworms prefer a dark, cool, well-aerated space, and thrive on moist bedding such as shredded newspaper. Kitchen food scraps placed in worm boxes are consumed by the worms and converted into worm castings, which can then be used like finished compost to grow plants. Vermicomposting is popular among children who like to watch the worms, and among adults who prefer the convenience of being able to make compost under their kitchen counter or in a household closet.

Although vermicomposting involves microorganisms as well

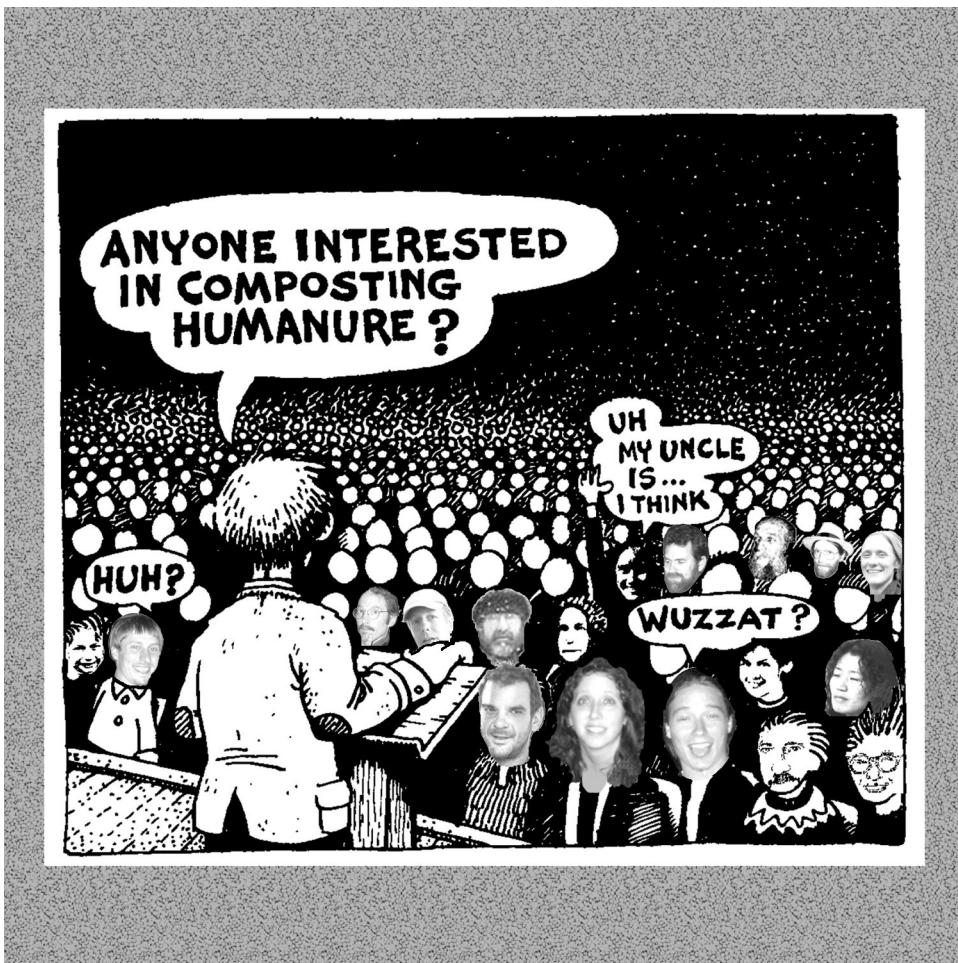
as earthworms, it is not the same as thermophilic composting. The hot stage of thermophilic composting will drive away all earthworms from the hot area of the compost pile. However, they will migrate back in after the compost cools down. Earthworms are reported to actually eat root-feeding nematodes, pathogenic bacteria and fungi, as well as small weed seeds.<sup>93</sup>

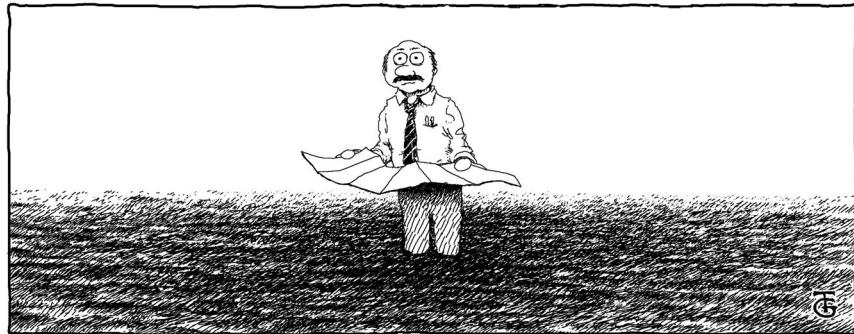
When thermophilic compost is piled on the bare earth, a large surface area is available for natural earthworms to migrate in and out of the compost pile. Properly prepared thermophilic compost situated on bare earth should require no addition of earthworms as they will naturally migrate into the compost when it best suits them. My compost is so full of natural earthworms at certain stages in its development that, when dug into, it looks like spaghetti. These worms are occasionally harvested and transformed into fish. This is a process which converts compost directly into protein, but which requires a fishing rod, a hook, and lots of patience.

### PRACTICE MAKES COMPOST

After reading this chapter one may become overwhelmed with all that is involved in composting: bacteria, actinomycetes, fungi, thermophiles, mesophiles, C/N ratios, oxygen, moisture, temperatures, bins, pathogens, curing and biodiversity. How do you translate this into your own personal situation and locate it all in your own backyard? How does one become an accomplished composter, a master composter? That's easy — just do it. Then keep doing it. Throw the books away (not this one, of course) and get some good, old-fashioned experience. There's no better way to learn. Book learning will only get you so far, but not far enough. A book such as this one is for inspiring you, for sparking your interest, and for reference. But you have to get out there and *do it* if you really want to learn.

Work with the compost, get the feel of the process, look at your compost, smell the finished product, buy or borrow a compost thermometer and get an idea of how well your compost is heating up, then use your compost for food production. Rely on your compost. Make it a part of your life. Need it and value it. In no time, without the need for charts or graphs, PhD.s, or worry, your compost will be as good as the best of them. Perhaps someday we'll be like the Chinese who give prizes for the best compost in a county, then have inter-county competitions. Now *that's* getting your shit together.





## DEEP SHIT

Shortly after I published the first edition of this book, I was invited to speak to a group of nuns at a convent. I had only printed 600 copies of the book and had assumed they would sit in my garage for the rest of my life because no one would be interested in the topic of composting “humanure.” Not long after, the Associated Press put the word out that I had written a book about crap. Then I got a phone call.

“Mr. Jenkins, we recently bought a copy of your book, *Humanure*, and we would like to have you speak at our convent.”

“What do you want me to talk about?”

“About the topic of your book.”

“Composting?”

“Yes, but specifically, *humanure* composting.” At this point I was at a loss for words. I couldn’t understand exactly why a group of nuns would be interested in composting human crap. Somehow, I couldn’t imagine standing in a room full of holy nuns, speaking about turds. But I kept the stammering to a minimum and accepted the invitation.

It was Earth Day, 1995. The presentation went well. After I spoke, the group showed slides of their gardens and compost piles, then we toured their compost area and poked around in the worm boxes. A delightful lunch followed, during which I asked them why they were interested in *humanure*, of all things.

“We are the Sisters of Humility,” they responded. “The words

*'humble' and 'humus' come from the same semantic root, which means 'earth.' We also think these words are related to the word 'human.' Therefore, as part of our vow of humility, we work with the earth. We make compost, as you've seen. And now we want to learn how to make compost from our toilet material. We're thinking about buying a commercial composting toilet, but we want to learn more about the overall concepts first. That's why we asked you to come here."* This was deep shit. Profound.

A light bulb went off in my head. Of course, composting is an act of humility. The people who care enough about the earth to recycle their personal by-products do so as an exercise in humility, not because they're going to get rich and famous for it. That makes them better people. Some people go to church on Sunday, others make compost. Still others do both. Others go to church on Sunday, then throw all their garbage out into the environment. The exercising of the human spirit can take many forms, and the simple act of cleaning up after oneself is one of them. The careless dumping of waste out into the world is a self-centered act of arrogance — or ignorance.

Humanure composters can stand under the stars at night gazing at the heavens, and know that, when nature calls, their excretions will not foul the planet. Instead, those excretions are humbly collected, fed to microorganisms and returned to the Earth as healing medicine for the soil.

## THE EGO VS. THE ECO

There are numerous theoretical reasons why we humans have strayed so far from a benign symbiotic relationship with the planet, and have instead taken on the visage, if not the behavior, of planetary pathogens. Human beings, like all living things on this planet, are inextricably intertwined with the elements of nature. We are threads in the tapestry of life. We constantly breathe the atmosphere that envelopes the planet; we drink the fluids that flow over the planet's surface; we eat the organisms that grow from the planet's skin. From the moment an egg and a sperm unite to spark our existence, each of us grows and develops from the elements provided by the Earth and sun. In essence, the soil, air, sun and water combine within our mother's womb to mold another living creature. Nine months later, another human being is born. That person is a separate entity, with an awareness of an individual self, an *ego*. That person is also totally a part of, and completely dependent upon, the surrounding natural world, the *eco*.

When the ego and the eco are balanced, the person lives in harmony with the planet. Such a balance can be considered to be the true meaning of *spirituality*, because the individual is a conscious part of, attuned to, and in harmony with a greater level of actual Being. When too much emphasis is placed on the self, the ego, an imbalance occurs and problems result, especially when that imbalance is collectively demonstrated by entire cultures. To suggest that these problems are only environmental and therefore not of great concern, is incorrect. Environmental problems (damage to the eco) ultimately affect all living things, as all living things derive their existence, livelihood and well-being from the planet. We cannot damage a thread in the web of life without the risk of fraying the entire tapestry.

When the ego gets blown out of proportion, we get thrown off balance in a variety of ways. Our educational institutions teach us to idolize the intellect, often at the expense of our moral, ethical, and spiritual development. Our economic institutions urge us to be consumers, and those who have gained the most material wealth are glorified. Our religious institutions often amount to little more than systems of human-worship where divinity is personified in human form and only human constructs (e.g., books and buildings) are considered sacred.

No discussion of a subject should be considered complete without an examination of its moral, philosophical and ethical considerations, *as well as* a review of the intellectual and scientific data. When we ignore the ethics behind a particular issue, and instead focus on intellectual achievements, it's great for our egos. We can pat ourselves on the back and tell ourselves how smart we are. It deflates our egos, on the other hand, to realize that we are actually insignificant creatures on a speck of dust in a corner of the universe, and that we are only one of the millions of life forms on this speck, all of whom must live together.

In recent decades, an entire generation of western scientists, a formidable force of intelligence, focused much of its efforts on developing new ways to kill huge numbers of human beings all at once. This was the nuclear arms race of the 1950s which continues through the present day — a race that left us with environmental disasters yet to be cleaned up, a huge amount of natural materials gone to total waste (5.5 trillion dollars worth),<sup>1</sup> a military death toll consisting of hundreds of thousands of innocent people, and the threat of nuclear annihilation hanging over all of the peace-loving peoples of

the world, even today. Surely this is an example of the collective ego run amok.

Religious movements that worship humans are ego-centered. It is ironic that a tiny, insignificant lifeform on a speck of dust at the edge of a galaxy lost somewhere in a corner of the universe would declare that the universe was created by one of their own kind. This would be a laughing matter if it were not taken so seriously by so many members of our culture who insist that the source of all life is a human-like creator deity named “God.”

Many humans have matured enough to know that this is simply myth. We can't begin to comprehend the full nature of our existence, so we *make up* a story that works until we figure out something better. Unfortunately, human-worship breeds an imbalanced collective ego. When we actually *believe* the myth, that humans are the pinnacle of life and the entire universe was created by one of our own species, we stray too far from truth and wander lost, with no point of reference to take us back to a balanced spiritual perspective we need for our own long-term survival on this planet. We become like a person knee deep in his own excrement, not knowing how to free himself from his unfortunate position, staring blankly at a road map with a look of utter incomprehension.

Today, new perspectives are emerging regarding the nature of human existence. The Earth itself is becoming recognized as a living entity, a level of Being immensely greater than the human level. The galaxy and universe are seen as even higher levels of Being, with multiverses (multiple universes) theorized as existing at a higher level yet. All of these levels of Being are thought to be imbued with the energy of life, as well as with a form of consciousness which we cannot even begin to comprehend. As we humans expand our knowledge of ourselves and recognize our true place in the vast scheme of things, our egos must defer to reality. We must admit our absolute dependence upon the ecosystem we call Earth, and try to balance our egotistical feelings of self-importance with our need to live in harmony with the greater world around us.

## ASIAN RECYCLING

The Asian people have recycled humanure for thousands of years. The Chinese have used humanure agriculturally since the Shang Dynasty, 3,000-4,000 years ago. Why haven't we westerners? The Asian cultures, namely Chinese, Korean, Japanese and others,

evolved to understand human excrement as a natural resource rather than a waste material. Where we had human waste, they had night soil. We produced waste and pollution; they produced soil nutrients and food. It's clear that Asians have been more advanced than the western world in this regard. And they should be, since they've been working on developing sustainable agriculture for four thousand years on the same land. For *four thousand years* these people have worked the same land with little or no chemical fertilizers and, in many cases, have produced greater crop yields than western farmers, who are quickly destroying the soils of their own countries through depletion and erosion.

A fact largely ignored by people in western agriculture is that *agricultural land must produce a greater output over time*. The human population is constantly increasing; available agricultural land is not. Therefore, our farming practices should leave us with land *more* fertile with each passing year. However, we are doing just the opposite.

Back in 1938, the U.S. Department of Agriculture came to the alarming conclusion that *a full 61% of the total area under crops in the U.S. at that time had already been completely or partly destroyed, or had lost most of its fertility*.<sup>2</sup> Nothing to worry about? We have artificial fertilizers, tractors and oil to keep it all going. True, U.S. agriculture is now heavily dependent upon fossil fuel resources. However, in 1993, we were importing about half our oil from foreign sources, and it's estimated that the U.S. will be out of domestic oil reserves by 2020.<sup>3</sup> A heavy dependence on foreign oil for our food production seems unwise *at best*, and probably just plain foolish, especially when we're producing soil nutrients every day in the form of organic refuse and throwing those nutrients "away" by burying them in landfills or incinerating them.

Why aren't we following the Asian example of agronutrient recycling? It's certainly not for a lack of information. Dr. F. H. King wrote an interesting book, published in 1910 titled Farmers of Forty Centuries.<sup>4</sup> Dr. King (D.Sc.) was a former chief of the Division of Soil Management of the U.S. Department of Agriculture who traveled through Japan, Korea and China in the early 1900s as an agricultural visitor. He was interested in finding out how people could farm the same fields for millennia without destroying their fertility. He states:

*"One of the most remarkable agricultural practices adopted by any civilized people is the centuries long and well nigh universal conservation and utilization of all [humanure] in China, Korea and Japan,*

*turning it to marvelous account in the maintenance of soil fertility and in the production of food. To understand this evolution it must be recognized that mineral fertilizers so extensively employed in modern Western agriculture have been a physical impossibility to all people alike until within very recent years. With this fact must be associated the very long unbroken life of these nations and the vast numbers their farmers have been compelled to feed.*

*When we reflect upon the depleted fertility of our own older farm lands, comparatively few of which have seen a century's service, and upon the enormous quantity of mineral fertilizers which are being applied annually to them in order to secure paying yields, it becomes evident that the time is here when profound consideration should be given to the practices the Mongolian race has maintained through many centuries, which permit it to be said of China that one-sixth of an acre of good land is ample for the maintenance of one person, and which are feeding an average of three people per acre of farm land in the three southernmost islands of Japan.*

*[Western humanity] is the most extravagant accelerator of waste the world has ever endured. His withering blight has fallen upon every living thing within his reach, himself not excepted; and his besom of destruction in the uncontrolled hands of a generation has swept into the sea soil fertility which only centuries of life could accumulate, and yet this fertility is the substratum of all that is living.”<sup>5</sup>*

According to King's research, the average daily excreta of the adult human weighs in at 40 ounces. Multiplied by 250 million, a rough estimate of the U.S. population in the late 20th century, Americans each year produced 1,448,575,000 pounds of nitrogen, 456,250,000 pounds of potassium, and 193,900,000 pounds of phosphorous. Almost all of it was discarded into the environment as a waste material or a pollutant, or as Dr. King puts it, “poured into the seas, lakes or rivers and into the underground waters.”

According to King, “*The International Concession of the city of Shanghai, in 1908, sold to a Chinese contractor the privilege of entering residences and public places early in the morning of each day and removing the night soil, receiving therefor more than \$31,000 gold, for 78,000 tons of [humanure]. All of this we not only throw away but expend much larger sums in doing so.*”

In case you didn't catch that, the contractor *paid* \$31,000 gold for the humanure, referred to as “night soil” and incorrectly as “waste” by Dr. King. People don't pay to buy waste, they pay money

for things of value.

Furthermore, using Dr. King's figures, the U.S. population produced approximately 228,125,000,000 pounds of fecal material annually in the late 20th century, or 228 billion pounds of *Gross National Product*.

Admittedly, the spreading of raw human excrement on fields, as is done in Asia, will never become culturally acceptable in the United States, and rightly so. The agricultural use of raw night soil produces an assault on the sense of smell, and provides a route of transmission for various human disease organisms. Americans who have traveled abroad and witnessed the use of raw human excrement in agricultural applications have largely been repulsed by the experience. That repulsion has instilled in many Americans an intransigent bias against, and even a fear of the use of humanure for soil enrichment. However, few Americans have witnessed the *composting* of humanure as a preliminary step in its recycling. Proper thermophilic composting converts humanure into a pleasant smelling material devoid of human pathogens.

Although the agricultural use of *raw* human excrement will never become a common practice in the U.S., the use of composted human refuse, including humanure, food refuse and other organic municipal refuse such as leaves, can and should become a widespread and culturally encouraged practice. The act of composting humanure instead of using it raw will set Americans apart from Asians in regard to the recycling of human excrements, *for we too will have to constructively deal with all of our organic byproducts eventually*. We can put it off, but not forever. As it stands now at least, many of the Asians are recycling much of their organic discards. We're not.

#### THE ADVANCES OF SCIENCE

How is it that Asian peoples developed an understanding of human nutrient recycling and we didn't? After all, we're the advanced, developed, scientific nation, aren't we? Dr. King makes an interesting observation concerning western scientists. He states:

*"It was not until 1888, and then after a prolonged war of more than thirty years, generated by the best scientists of all Europe, that it was finally conceded as demonstrated that leguminous plants acting as hosts for lower organisms living on their roots are largely responsible for the maintenance of soil nitrogen, drawing it directly from the air*

*to which it is returned through the processes of decay. But centuries of practice had taught the Far East farmers that the culture and use of these crops are essential to enduring fertility, and so in each of the three countries the growing of legumes in rotation with other crops very extensively, for the express purpose of fertilizing the soil, is one of their old fixed practices.”<sup>6</sup>*

It certainly seems odd that people who gain their knowledge in real life through practice and experience are largely ignored or trivialized by the academic world and associated government agencies. Such agencies only credit learning that has taken place within an institutional framework. As such, it’s no wonder that Western humanity’s crawl toward a sustainable existence on the planet Earth is so pitifully slow.

*“Strange as it may seem,” says King, “there are not today and apparently never have been, even in the largest and oldest cities of Japan, China or Korea, anything corresponding to the hydraulic systems of sewage disposal used now by Western nations. When I asked my interpreter if it was not the custom of the city during the winter months to discharge its night soil into the sea, as a quicker and cheaper mode of disposal [than recycling], his reply came quick and sharp, ‘No, that would be waste. We throw nothing away. It is worth too much money.’ ”<sup>7</sup> “The Chinaman,” says King, “wastes nothing while the sacred duty of agriculture is uppermost in his mind.”<sup>8</sup>*

Perhaps, someday, we also will understand.

#### WHEN THE CRAP HIT THE FAN

While the Asians were practicing sustainable agriculture and recycling their organic resources and doing so over millennia, what were the people of the West doing? What were the Europeans and those of European descent doing? Why weren’t our European ancestors returning their manures to the soil, too? After all, it does make sense. The Asians who recycled their manures not only recovered a resource and reduced pollution, but by returning their excrement to the soil, they succeeded in reducing threats to their health. There was no putrid sewage collecting and breeding disease germs. Instead, the humanure was, for the most part, undergoing a natural, non-chemical purification process in the soil which required no technology.

Granted, a lot of “night soil” in the Far East today is not composted and is the source of health problems. However, even the returning of humanure raw to the land succeeds in destroying many human pathogens in the manure and returns nutrients to the soil.

Let’s take a look at what was happening in Europe regarding public hygiene from the 1300s on. Great pestilences swept Europe throughout recorded history. The Black Death killed more than half the population of England in the fourteenth century. In 1552, 67,000 patients died of the Plague in Paris alone. Fleas from infected rats were the carriers of this disease. Did the rats dine on human waste? Other pestilences included the sweating sickness (attributed to uncleanliness), cholera (spread by food and water contaminated by the excrement of infected persons), “jail fever” (caused by a lack of sanitation in prisons), typhoid fever (spread by water contaminated with infected feces), and numerous others.

Andrew D. White, cofounder of Cornell University, writes, “*Nearly twenty centuries since the rise of Christianity, and down to a period within living memory, at the appearance of any pestilence the Church authorities, instead of devising sanitary measures, have very generally preached the necessity of immediate atonement for offenses against the Almighty. In the principal towns of Europe, as well as in the country at large, down to a recent period, the most ordinary sanitary precautions were neglected, and pestilences continued to be attributed to the wrath of God or the malice of Satan.*”<sup>9</sup>

It’s now known that the main cause of such immense sacrifice of life was a lack of proper hygienic practices. It’s argued that certain theological reasoning at that time resisted the evolution of proper hygiene. According to White, “*For century after century the idea prevailed that filthiness was akin to holiness.*” Living in filth was regarded by holy men as evidence of sanctity, according to White, who lists numerous saints who never bathed parts or all of their bodies, such as St. Abraham, who washed neither his hands nor his feet for fifty years, or St. Sylvia, who never washed any part of her body except her fingers.<sup>10</sup>

Interestingly, after the Black Death left its grim wake across Europe, “*an immensely increased proportion of the landed and personal property of every European country was in the hands of the church.*”<sup>11</sup> Apparently, the church was reaping some benefit from the deaths of huge numbers of people. Perhaps the church had a vested interest in maintaining public ignorance about the sources of disease. This insinuation is almost too diabolical for serious consideration. Or is it?

Somehow, the idea developed around the 1400s that Jews and witches were causing the pestilences. Jews were suspected because they didn't succumb to the pestilences as readily as the Christian population did, presumably because they employed a unique sanitation system more conducive to cleanliness, including the eating of kosher foods. Not understanding this, the Christian population arrived at the conclusion that the Jews' immunity resulted from protection by Satan. As a result, attempts were made in all parts of Europe to stop the plagues by torturing and murdering the Jews. Twelve thousand Jews were reportedly burned to death in Bavaria alone during the time of the plague, and additionally thousands more were likewise killed throughout Europe.<sup>12</sup>

In 1484, the "infallible" Pope Innocent VIII issued a proclamation supporting the church's opinion that witches were causes of disease, storms, and a variety of ills affecting humanity. The feeling of the church was summed up in one sentence: "*Thou shalt not suffer a witch to live.*" From the middle of the sixteenth to the middle of the seventeenth centuries, women *and* men were sent to torture and death by the thousands by both Protestant and Catholic authorities. It's estimated that the number of victims sacrificed during that century in Germany alone was over a hundred thousand.

The following case in Milan, Italy, summarizes the ideas of sanitation in Europe during the seventeenth century:

The city was under the control of Spain, and it had received notice from the Spanish government that witches were suspected to be en route to Milan to "anoint the walls" (smear the walls with disease-causing ointments). The church rang the alarm from the pulpit, putting the population on the alert. One morning in 1630, an old woman looking out her window saw a man who was walking along the street wipe his fingers on a wall. He was promptly reported to the authorities. He claimed he was simply wiping ink from his fingers which had rubbed off the ink-horn he carried with him. Not satisfied with this explanation, the authorities threw the man into prison and tortured him until he "confessed." The torture continued until the man gave the names of his "accomplices," who were subsequently rounded up and tortured. They in turn named *their* "accomplices" and the process continued until members of the foremost families were included in the charges. Finally, a large number of innocent people were sentenced to their deaths, all of this reportedly being a matter of record.<sup>13</sup>

One loathsome disease of the 1500s through the 1700s was the

“jail fever.” The prisons of that period were filthy. People were confined in dungeons connected to sewers with little ventilation or drainage. Prisoners incubated the disease and spread it to the public, especially to the police, lawyers and judges. In 1750, for example, the disease killed two judges, the lord mayor, various aldermen and many others in London, including of course, prisoners.<sup>14</sup>

The pestilences at that time in the Protestant colonies *in America* were also attributed to divine wrath or satanic malice, but when the diseases afflicted the Native Americans, they were considered beneficial. “*The pestilence among the Indians, before the arrival of the Plymouth Colony, was attributed in a notable work of that period to the Divine purpose of clearing New England for the heralds of the gospel.*”<sup>15</sup>

Perhaps the reason the Asian countries have such large populations in comparison to Western countries is because they escaped some of the pestilences common to Europe, especially pestilences spread by the failure to responsibly recycle human excrement. They presumably plowed their manure back into the land because their spiritual perspectives supported such behavior. Westerners were too busy burning witches and Jews with the church’s wholehearted assistance to bother thinking about recycling humanure.

Our ancestors did, eventually, come to understand that poor hygiene was a causal factor in epidemic diseases. Nevertheless, it was not until the late 1800s in England that improper sanitation and sewage were suspected as causes of epidemics. At that time, large numbers of people were still dying from pestilences, especially cholera, which killed at least 130,000 people in England in 1848-9 alone. In 1849, an English medical practitioner published the theory that cholera was spread by water contaminated with sewage. Ironically, even where sewage was being piped away from the population, the sewers were still leaking into drinking water supplies.

The English government couldn’t be bothered with the fact that hundreds of thousands of mostly poor citizens were perishing like flies year after year. So it rejected a Public Health Bill in 1847. A Public Health Bill finally became an Act in 1848 in the face of the latest outbreak, but wasn’t terribly effective. However, it did bring poor sanitation to the attention of the public, as the following statement from the General Board of Health (1849) implies: “*Householders of all classes should be warned that their first means of safety lies in the removal of dung heaps and solid and liquid filth of every description from beneath or about their houses and premises.*” This may make one wonder if a compost pile would have been considered a “dung heap” in those days,

and therefore banned.

Sanitation in England was so bad in the mid-to-late eighteen hundreds that, “*In 1858, when the Queen and Prince Albert had attempted a short pleasure cruise on the Thames, its malodorous waters drove them back to land within a few minutes. That summer a prolonged wave of heat and drought exposed its banks, rotten with the sewage of an overgrown, undrained city. Because of the stench, Parliament had to rise early.*” Another story describes Queen Victoria gazing out over the river and asking aloud what the pieces of paper were that so abundantly floated by. Her companion, not wanting to admit that the Queen was looking at pieces of used toilet paper, replied, “*Those, Ma’am, are notices that bathing is forbidden.*”<sup>16</sup>

The Tories or “conservatives” of the English government still thought that spending on social services was a waste of money and an unacceptable infringement by the government on the private sector (sound familiar?). A leading newspaper, “The Times,” maintained that the risk of cholera was preferable to being bullied by the government into providing sewage services. However, a major Act was finally passed in 1866, the Public Health Act, with only grudging support from the Tories. Once again, cholera was raging through the population, and it’s probably for that reason that any act was passed at all. Finally, by the end of the 1860s, a framework of public health policy was established in England. Thankfully, the cholera epidemic of 1866 was the last and the least disastrous.<sup>17</sup>

The powers of the church eventually diminished enough for physicians to have their much-delayed say about the origins of disease. Our modern sanitation systems have finally yielded a life safe for most of us, although not without shortcomings. The eventual solution developed by the west was to collect humanure in water and discard it, perhaps chemically treated, incinerated or dehydrated — into the seas, into the atmosphere, onto the surface of the land, and into landfills.

#### ASIAN UPDATE

It would be naive to suggest that the Asian societies are perfect by any stretch of the imagination. Asian history is rife with the problems that have plagued humanity since the first person slid out of the first womb. Those problems include such things as oppressive rule by the rich, war, famine, natural catastrophes, oppressive rule by heathens, more war, and now overpopulation.

Today, Asians are abandoning the harmonious agricultural techniques that Dr. King observed nearly a century ago. In Kyoto, Japan, for example, “*night soil is collected hygienically to the satisfaction of users of the system, only to be diluted at a central collection point for discharge to the sewer system and treatment at a conventional sewage treatment plant.*”<sup>18</sup>

A Humanure Handbook reader wrote an interesting account of Japanese toilets in a letter to the author, which is paraphrased here:

*“My only real [humanure] experience....comes from living in Japan from 1973-1983. As my experience is dated, things may have changed (probably for the worse as toilets and life were becoming ‘westernized’ even toward the end of my stay in Japan).*

*My experience comes from living in small, rural towns as well as in metropolitan areas (provincial capitals). Homes/businesses had an ‘indoor outhouse.’ The Vault: Nothing but urine/feces were deposited into the large metal vault under the toilet (squat style, slightly recessed in the floor and made of porcelain). No cover material or carbonaceous stuff was used. It stunk !! Not just the bathroom, but the whole house! There were many flies, even though the windows were screened. Maggots were the main problem. They crawled up the sides of the vault onto the toilet and floor and sometimes even made it outside the bathroom into the hall. People constantly poured some kind of toxic chemical into the vaults to control the smell and maggots. (It didn’t help — in fact, the maggots really poured out of the vault to escape the chemicals.) Occasionally a slipper (one put on special ‘bathroom slippers’ as opposed to ‘house slippers’ when entering the bathroom) fell into the disgusting liquid/maggot-filled vault. You couldn’t even begin to think about getting it out! You couldn’t let little children use the toilet without an adult suspending them over it. They might fall in! Disposal: When the vault was full (about every three months), you called a private vacuum truck which used a large hose placed in an outside opening to suck out the liquid mass. You paid them for their services. I’m not sure exactly what happened to the humanure next but, in the agricultural areas near the fields were large (10 feet in diameter) round, concrete, raised containers, similar in looks to an above ground swimming pool. In the containers, I was told, was the humanure from the ‘vacuum trucks.’ It was a greenish-brown liquid with algae growing on the surface. I was told this was spread onto agricultural fields.”*

In 1952, about 70% of Chinese humanure was recycled. This had increased to 90% by 1956, and constituted a third of all fertilizer used in the country.<sup>19</sup> Lately, however, humanure recycling in China seems to be going downhill. The use of synthetic fertilizers has risen over 600% between the mid 1960s to the mid 1980s, and now China’s average annual fertilizer usage per hectare is estimated to be double that of the world’s average. Between 1949 and 1983, agricultural

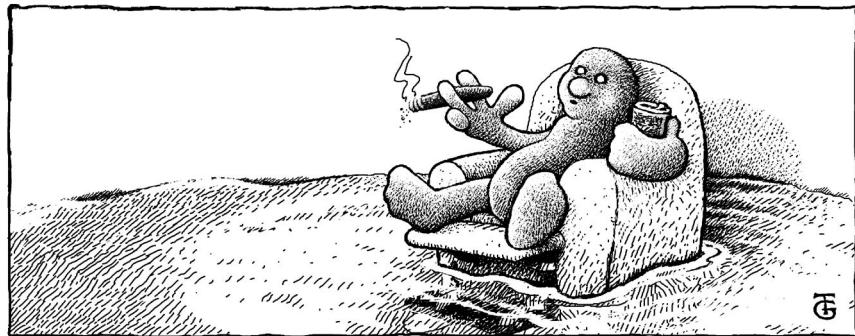
nitrogen and phosphorous inputs increased by a factor of ten, while agricultural yields only tripled.<sup>20</sup>

Water pollution in China began to increase in the 1950s due to the discarding of sewage into water. Now, about 70% of China's wastewater is said to be dumped into China's main rivers. By 1992, 45 billion tonnes of wastewater were flowing into China's rivers and lakes annually, 70% untreated. In urban areas, 80% of the surface water is polluted with nitrogen and ammonia, and most lakes around cities have become dumping grounds for large quantities of sewage. It is estimated that 450,000 tonnes of humanure are dumped into the Huangpu River alone in a year. Half a million cases of hepatitis A, spread by polluted water, occurred in Shanghai in 1988. Soil-borne diseases, practically non-existent in China twenty years ago, are now also causing problems. *“Increasingly, Chinese urban authorities are turning to incineration or landfill as the ways of disposing of their solid wastes rather than recycling and composting, which means that China, like the west, is putting the problem onto the shoulders of future generations.”*<sup>21</sup>

For a sense of historical perspective, I'll leave you with a quote from Dr. Arthur Stanley, health officer of the city of Shanghai, China, in his annual report for 1899, when the population of China amounted to about 500 million people. At that time, no artificial fertilizers were employed for agricultural purposes — only organic, natural materials such as agricultural residues and humanure were being used:

*“Regarding the bearing on the sanitation of Shanghai of the relationship between Eastern and Western hygiene, it may be said, that if prolonged national life is indicative of sound sanitation, the Chinese are a race worthy of study by all who concern themselves with public health. It is evident that in China the birth rate must very considerably exceed the death rate, and have done so in an average way during the three or four thousand years that the Chinese nation has existed. Chinese hygiene, when compared to medieval English, appears to advantage.”*<sup>22</sup>

Sounds like an understatement to me.



G

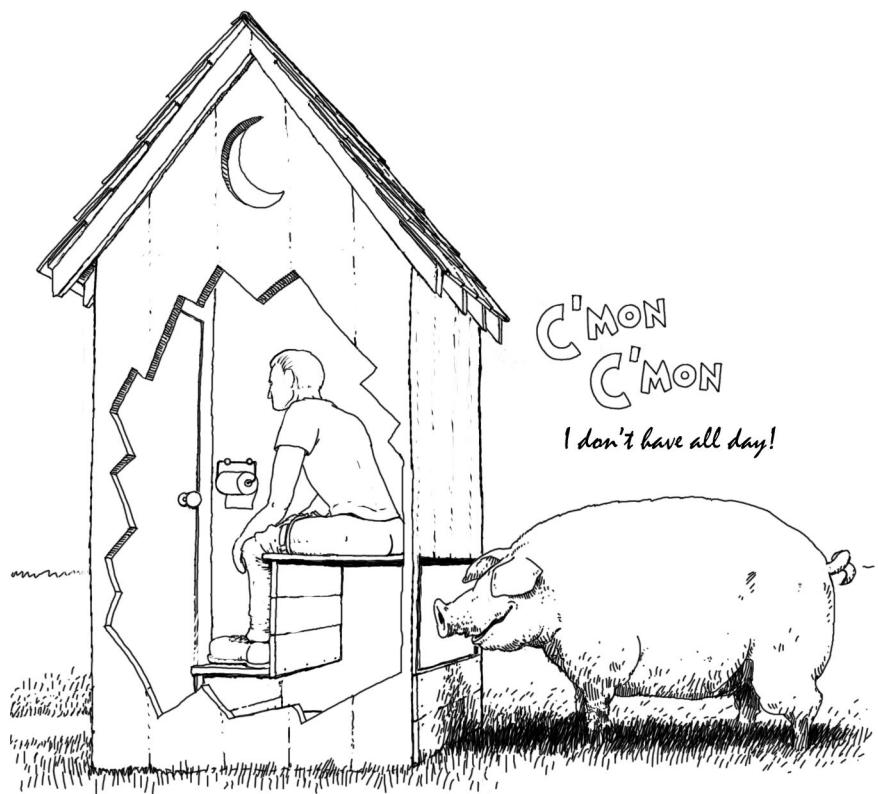
## A DAY IN THE LIFE OF A TURD

**W**hen I was a kid, I listened to army veterans talking about their stints in the Korean War. Usually after a beer or two, they'd turn their conversation to the "outhouses" used by the Koreans. They were amazed, even mystified, about the fact that the Koreans tried to lure passersby into their outhouses by making the toilets especially attractive. The idea of someone wanting someone else's crap always brought out a loud laugh from the vets.

Perhaps this attitude sums up the attitudes of Americans. Humanure is a waste product that we have to get rid of, and that's all there is to it. Only fools would think otherwise. One of the effects of this sort of attitude is that Americans don't know and probably don't care where their humanure goes after it emerges from their rear ends as long as they don't have to deal with it.

### MEXICAN BIOLOGICAL DIGESTER

Well, where it goes depends on the type of "waste disposal system" used. Let's start with the simplest: the Mexican biological digester, also known as the stray dog. In India, this may be known as the family pig. I spent a few months in southern Mexico in the late 1970s in Quintana Roo on the Yucatan peninsula. There, toilets were not available; people simply used the sand dunes along the coast. No problem, though. One of the small, unkempt and ubiquitous Mexican dogs would wait nearby with watering mouth until you did your



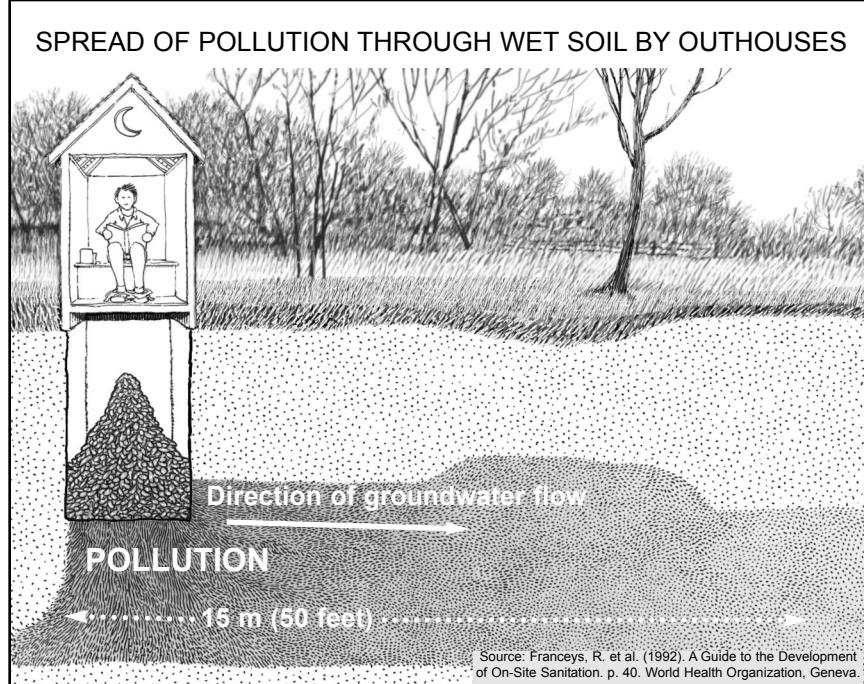
PRIMITIVE BIOLOGICAL DIGESTER

thing. Burying your excrement in that situation would have been an act of disrespect to the dog. No one wants sand in their food. A good, healthy, steaming turd at the crack of dawn on the Caribbean coast never lasted more than 60 seconds before it became a hot meal for a human's best friend. Yum.

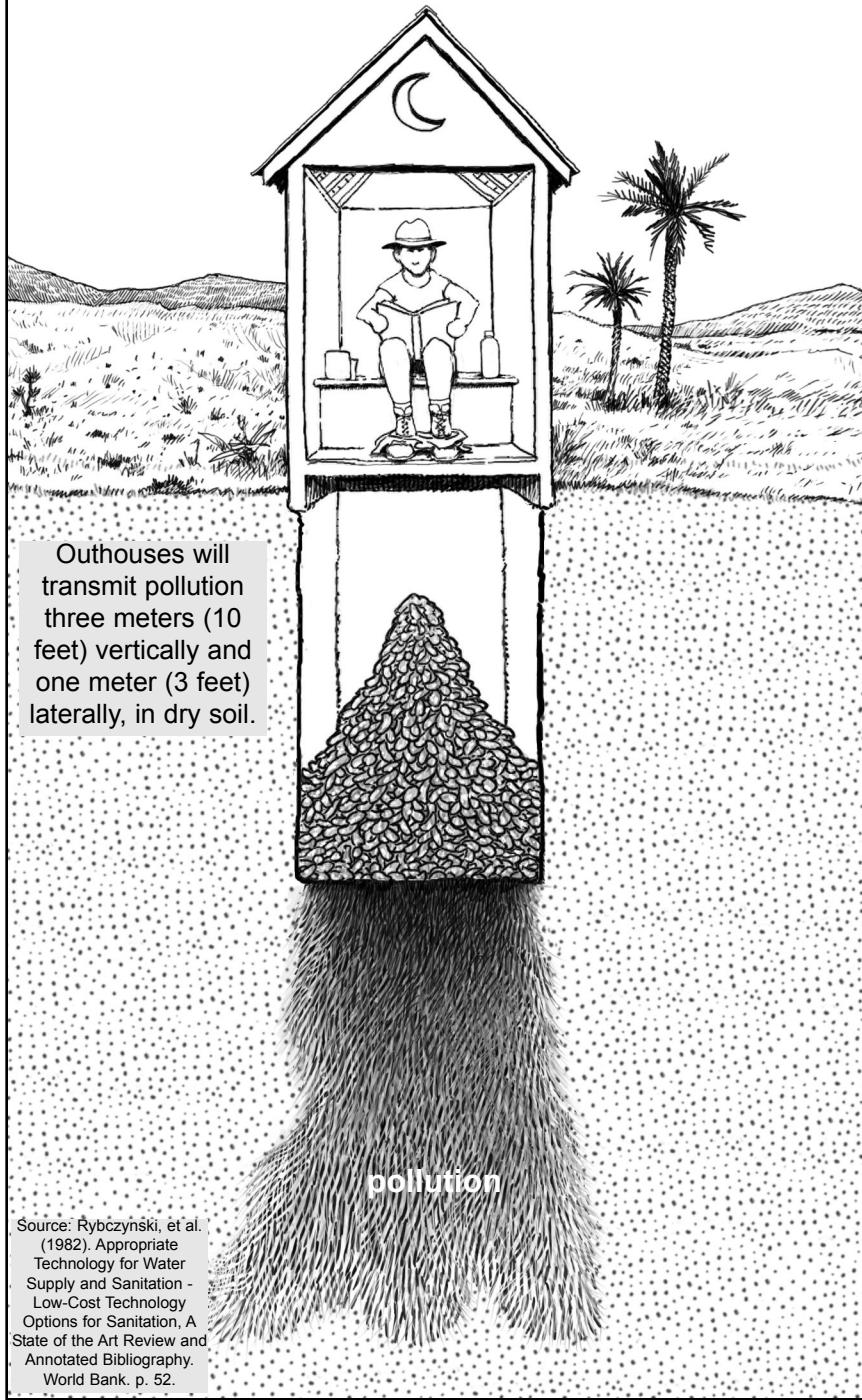
### THE OLD-FASHIONED OUTHOUSE

Next up the ladder of sophistication is the old-fashioned outhouse, also known as the pit latrine. Simply stated, one digs a hole and defecates in it, and then does so again and again until the hole fills up; then it's covered with dirt. It's nice to have a small building or "privy" over the hole to provide some privacy and shelter. However, the concept is simple: dig a hole and bury your excrement. Interestingly, this level of sophistication has not yet been surpassed in America. We still bury our excrement, in the form of sewage sludge, in landfill holes.

Outhouses create very real health, environmental and aesthetic problems. The hole in the ground is accessible to flies and mosquitoes which can transmit diseases over a wide area. The pits leak pollutants into the ground even in dry soil. And the smell — *hold your*



### SPREAD OF POLLUTION THROUGH DRY SOIL BY OUTHOUSES



*nose.*

Outhouses will transmit pollution three meters (10 feet) below the outhouse hole and one meter (3 feet) sideways in dry soil. They can be expected to leak pollution 50 feet sideways in wet soils, following the direction of groundwater flow.

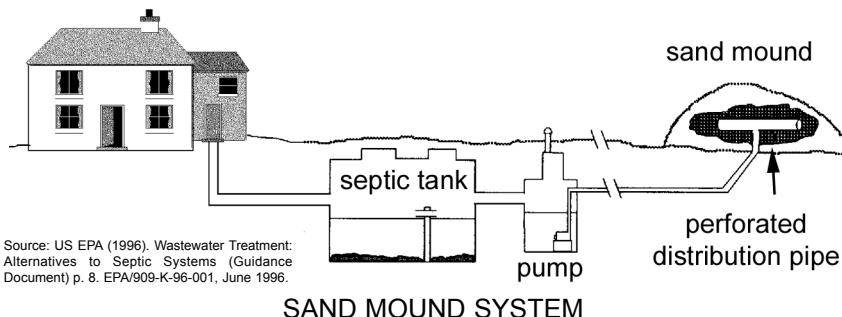
## SEPTIC SYSTEMS

Another step up the ladder, one finds the septic tank, a common method of human waste disposal in rural and suburban areas of the United States. In this system the turd is deposited into a container of water, usually purified drinking water, and flushed away.

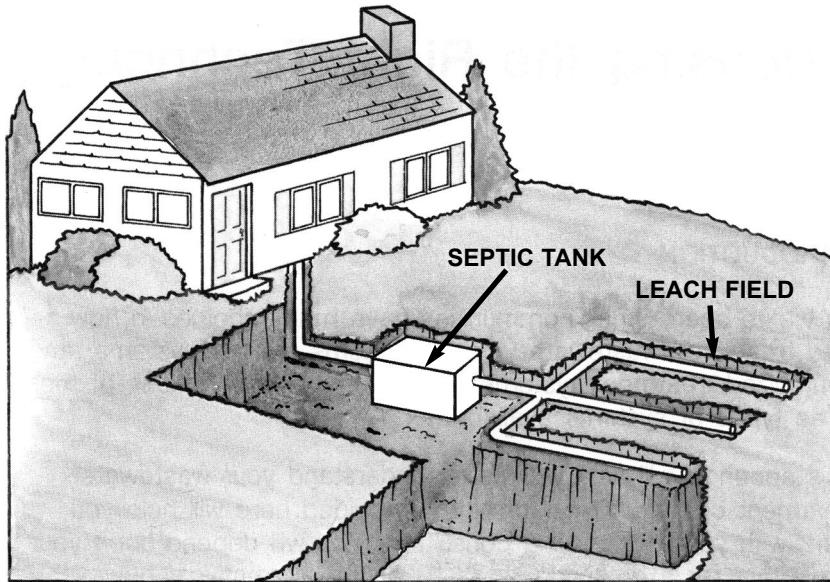
After the floating turd travels through a sewage pipe, it plops into a fairly large underground storage tank, or septic tank, usually made of concrete and sometimes of fiberglass. In Pennsylvania (U.S.), a 900 gallon tank is the minimum size allowed for a home with three or fewer bedrooms.<sup>1</sup> The heavier solids settle to the bottom of the tank and the liquids drain off into a leach field, which consists of an array of drain pipes situated below the ground surface allowing the liquid to seep out into the soil. The wastewater is expected to be undergoing anaerobic decomposition while in the tank. When septic tanks fill up, they are pumped out and the waste material is trucked to a sewage treatment plant, although sometimes it's illegally dumped.

## SAND MOUNDS

In the event of poorly drained soil, either low-lying or with a high clay content, a standard leach field will not work very well, especially when the ground is already saturated with rainwater or snow melt. One can't drain wastewater into soil that is already saturated with water. That's when the *sand mound* sewage disposal system is

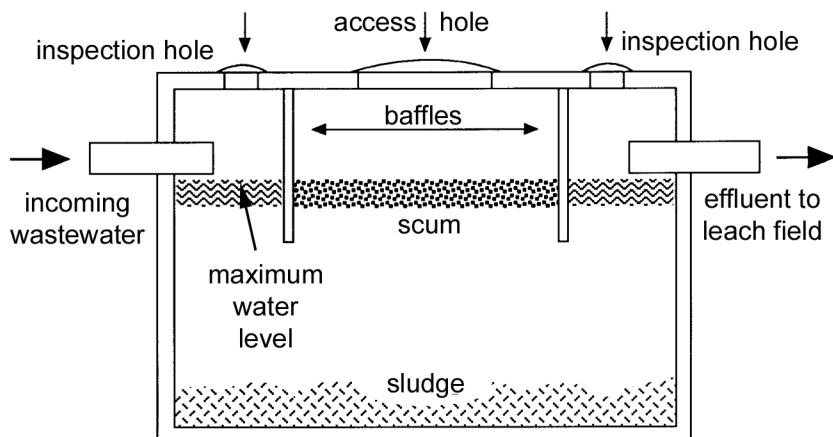


SAND MOUND SYSTEM



### STANDARD SEPTIC TANK GRAVITY DISTRIBUTION SYSTEM

Source: US EPA (1987). *It's Your Choice — A Guidebook for Local Officials on Small Community Wastewater Management Options*, p. 40. EPA 430/9-87-006.



### CROSS-SECTION OF A SEPTIC TANK

Source: Penn State College of Agriculture, Cooperative Extension, Agricultural Engineering Fact Sheet SW-165.

employed. When the septic tank isn't draining properly, a pump will kick in and pump the effluent into a pile of sand and gravel above ground (although sometimes a pump isn't necessary and gravity does the job). A perforated pipeline in the pile of sand allows the effluent to drain down through the mound. Sand mounds are usually covered with soil and grass. In Pennsylvania, sand mounds must be at least one hundred feet downslope from a well or spring, fifty feet from a stream, and five feet from a property line.<sup>2</sup> According to local excavating contractors, sand mounds cost \$5,000 to \$12,000 to construct in the early 21st century. They must be built to exact government specifications, and aren't usable until they pass an official inspection.

#### GROUND WATER POLLUTION FROM SEPTIC SYSTEMS



**IF you have a  
Septic Tank System...**

Humans started disposing of "human waste" by defecating into a hole in the ground or an outhouse, then discovered we could float our turds out to the hole using water and never have to leave our shelter. However, one of the unfortunate problems with septic systems is, like outhouses, they pollute our groundwater.

At the end of the 20th century, there were 22 million septic system sites in the United States, serving one fourth to one third of the U.S. population. They were notorious for leaching contaminants such as bacteria, viruses,

nitrates, phosphates, chlorides and organic compounds such as trichloroethylene into the environment. An EPA study of chemicals in septic tanks found toluene, methylene chloride, benzene, chloroform and other volatile synthetic organic compounds related to home chemical use, many of them cancer-causing.<sup>3</sup> Between 820 and 1,460 billion gallons of this contaminated water were discharged per year into our shallowest aquifers.<sup>4</sup> In the U.S., septic tanks are reported as a source of ground water contamination more than any other source. Forty-six states cite septic systems as sources of groundwater pollution; nine of these reported them to be the primary source of groundwater contamination in their state.<sup>5</sup>

The word "septic" comes from the Greek "septikos" which

means “to make putrid.” Today it still means “causing putrefaction,” putrefaction being “the decomposition of organic matter resulting in the formation of foul-smelling products.” Septic systems are not designed to destroy human pathogens that may be in the human waste that enters the septic tank. Instead, septic systems are designed to collect human wastewater, settle out the solids, and anaerobically digest them to some extent, leaching the effluent into the ground. Therefore, septic systems can be highly pathogenic, allowing the transmission of disease-causing bacteria, viruses, protozoa and intestinal parasites through the system.

One of the main concerns associated with septic systems is the problem of human population density. Too many septic systems in any given area will overload the soil’s natural purification systems and allow large amounts of wastewater to contaminate the underlying watertable. A density of more than forty household septic systems per square mile will cause an area to become a likely target for subsurface contamination, according to the EPA.<sup>6</sup>

Toxic chemicals are commonly released into the environment from septic systems because people dump them down their drains. The chemicals are found in pesticides, paint, toilet cleaners, drain cleaners, disinfectants, laundry solvents, antifreeze, rust proofers, septic tank and cesspool cleaners and many other cleaning solutions. In fact, over 400,000 gallons of septic tank cleaner liquids containing synthetic organic chemicals were used in one year by the residents of Long Island alone. Furthermore, some toxic chemicals can corrode pipes, thereby causing heavy metals to enter septic systems.<sup>7</sup>

In many cases, people who have septic tanks are forced to connect to sewage lines when the lines become available. A U.S. Supreme Court case in 1992 reviewed a situation whereby town members in New Hampshire had been forced to connect to a sewage line that simply discharged untreated, raw sewage into the Connecticut River, and had done so for 57 years. Despite the crude method of sewage disposal, state law required properties within 100 feet of the town sewer system to connect to it from the time it was built in 1932. This barbaric sewage disposal system apparently continued to operate until 1989, when state and federal sewage treatment laws forced a stop to the dumping of raw sewage into the river.<sup>8</sup>

## WASTEWATER TREATMENT PLANTS

There's still another step up the ladder of wastewater treatment sophistication: the wastewater treatment plant, or sewage plant. The wastewater treatment plant is like a huge, very sophisticated septic tank because it collects the waterborne excrement of large numbers of humans. Inevitably, when one defecates or urinates into water, one pollutes the water. In order to avoid environmental pollution, that "wastewater" must somehow be rendered fit to return to the environment. The wastewater entering the treatment plant is 99% liquid because all sink water, bath water and everything else that goes down one's drain ends up at the plant too, which is why it's called a *water* treatment plant. In some cases, storm water runoff also enters wastewater treatment plants via *combined sewers*. Industries, hospitals, gas stations and any place with a drain add to the contaminant blend in the wastewater stream.

Many modern wastewater plants use a process of activated sludge treatment whereby oxygen is vigorously bubbled through the wastewater in order to activate microbial digestion of the solids. This aeration stage is combined with a settling stage that allows the solids to be removed. The removed solids, known as *sludge*, are either used to reinoculate the incoming wastewater, or they're dewatered to the consistency of a dry mud and buried in landfills. Sometimes the sludge is applied to agricultural land, and now, sometimes, it's composted.

The microbes that digest the sludge consist of bacteria, fungi, protozoa, rotifers and nematodes.<sup>9</sup> U.S. sewage treatment plants generated about 7.6 million dry tons of sludge in 1989.<sup>10</sup> New York City alone produces 143,810 dry tons of sludge every year.<sup>11</sup> In 1993, the amount of sewage sludge produced annually in the U.S. was 110-150 million wet metric tons. The water left behind is treated, usually with chlorine, and discharged into a stream, river or other body of water. Sewage treatment water releases to surface water in the United States in 1985 amounted to nearly *31 billion gallons per day*.<sup>12</sup> Incidentally, the amount of toilet paper used in 1991 to send all this waste to the sewers was 2.3 million tons.<sup>13</sup> With each passing year, as the human population increases, these figures go up.

## WASTE STABILIZATION PONDS

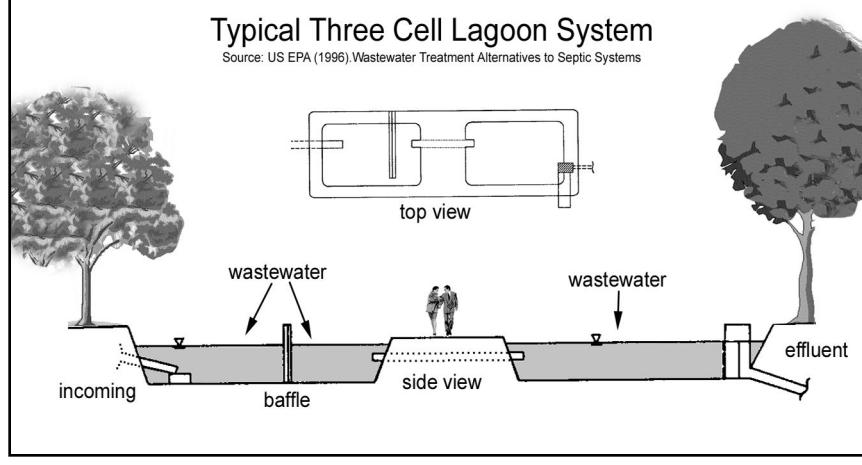
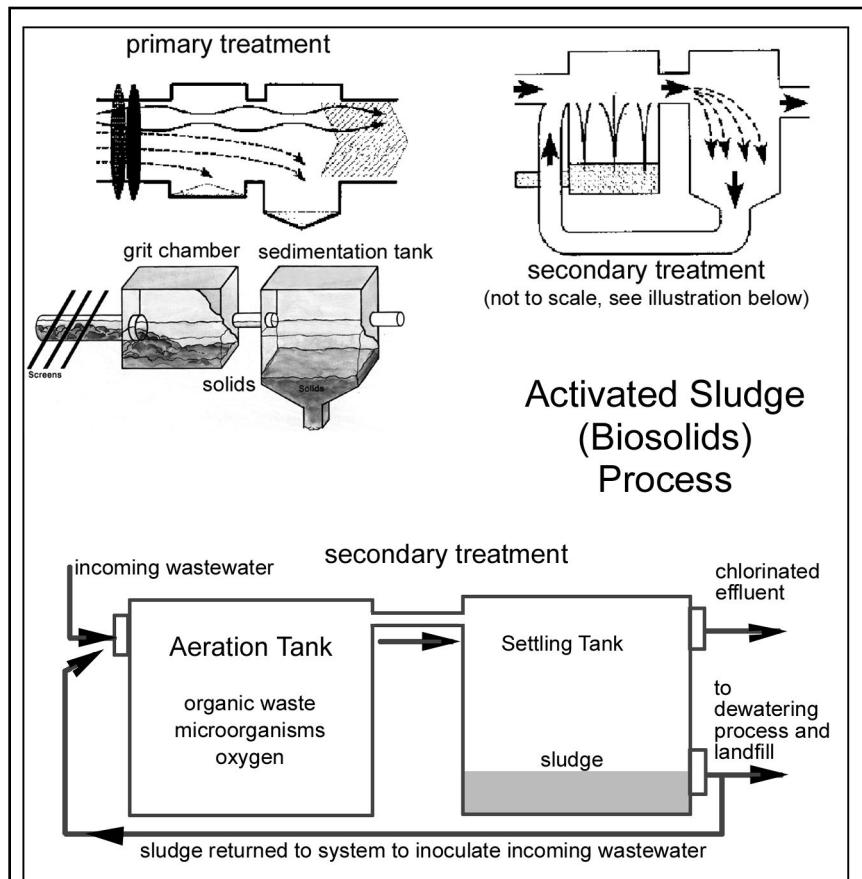
Perhaps one of the most ancient wastewater treatment methods known to humans are waste stabilization ponds, also known as oxidation ponds or lagoons. They're often found in small rural areas where land is available and cheap. Such ponds tend to be only a meter to a meter and a half deep, but vary in size and depth and can be three or more meters deep.<sup>14</sup> They utilize natural processes to "treat" waste materials, relying on algae, bacteria and zooplankton to reduce the organic content of the wastewater. A "healthy" lagoon will appear green in color because of the dense algae population. These lagoons require about one acre for every 200 people served. Mechanically aerated lagoons only need 1/3 to 1/10 the land that unaerated stabilization ponds require. It's a good idea to have several smaller lagoons in series rather than one big one; normally, a minimum of three "cells" are used. Sludge collects in the bottom of the lagoons, and may have to be removed every five or ten years and disposed of in an approved manner.<sup>15</sup>

## CHLORINE

Wastewater leaving treatment plants is often treated with chlorine before being released into the environment. Therefore, besides contaminating water resources with feces, the act of defecating into water often ultimately contributes to the contamination of water resources with *chlorine*.

Used since the early 1900s, chlorine is one of the most widely produced industrial chemicals. More than 10 million metric tons are manufactured in the U.S. each year — \$72 billion worth.<sup>16</sup> Annually, approximately 5%, or 1.2 billion pounds of the chlorine manufactured is used for wastewater treatment and drinking water "purification." The lethal liquid or green gas is mixed with the wastewater from sewage treatment plants in order to kill disease-causing microorganisms before the water is discharged into streams, lakes, rivers and seas. It is also added to household drinking water via household and municipal water treatment systems. Chlorine kills microorganisms by damaging their cell membranes, which leads to a leakage of their proteins, RNA, and DNA.<sup>17</sup>

Chlorine ( $\text{Cl}_2$ ) doesn't exist in nature. It's a potent poison which reacts with water to produce a strongly oxidizing solution that can damage the moist tissue lining of the human respiratory tract.



Ten to twenty parts per million (ppm) of chlorine gas in air rapidly irritates the respiratory tract; even brief exposure at levels of 1,000 ppm (one part in a thousand) can be fatal.<sup>18</sup> Chlorine also kills fish, and reports of fish kills caused chlorine to come under the scrutiny of scientists in the 1970s.

The fact that harmful compounds are formed as *by-products* of chlorine use also raises concern. In 1976, the U.S. Environmental Protection Agency reported that chlorine use not only poisoned fish, but could also cause the formation of cancer-causing compounds such as chloroform. Some known effects of chlorine-based pollutants on animal life include memory problems, stunted growth and cancer in humans; reproductive problems in minks and otters; reproductive problems, hatching problems and death in lake trout; and embryo abnormalities and death in snapping turtles.<sup>19</sup>

In a national study of 6,400 municipal wastewater treatment plants, the EPA estimated that two thirds of them used too much chlorine, exerting lethal effects at all levels of the aquatic food chain. Chlorine damages the gills of fish, inhibiting their ability to absorb oxygen. It also can cause behavioral changes in fish, thereby affecting migration and reproduction. Chlorine in streams can create chemical “dams” which prevent the free movement of some migratory fish. Fortunately, since 1984, there has been a 98% reduction in the use of chlorine by sewage treatment plants, although chlorine use continues to be a widespread problem because a lot of wastewater plants are still discharging it into small receiving waters.<sup>20</sup>

Another controversy associated with chlorine use involves “dioxin,” which is a common term for a large number of chlorinated chemicals that are classified as possible human carcinogens by the EPA. It’s known that dioxins cause cancer in laboratory animals, but their effects on humans are still being debated. Dioxins, by-products of the chemical manufacturing industry, are concentrated up through the food chain where they’re deposited in human fat tissues. A key ingredient in the formation of dioxin is chlorine, and indications are that an increase in the use of chlorine results in a corresponding increase in the dioxin content of the environment, even in areas where the only dioxin source is the atmosphere.<sup>21</sup>

In the upper atmosphere, chlorine molecules from air pollution gobble up ozone; in the lower atmosphere, they bond with carbon to form organochlorines. Some of the 11,000 commercially used organochlorines include hazardous compounds such as DDT, PCBs, chloroform and carbon tetrachloride. Organochlorines rarely occur in

nature, and living things have little defense against them. They've been linked not only to cancer, but also to neurological damage, immune suppression and reproductive and developmental effects. When chlorine products are washed down the drain into a septic tank, they're producing organochlorines. Although compost microorganisms can degrade and make harmless many toxic chemicals, highly chlorinated compounds are disturbingly resistant to such biodegradation.<sup>22</sup>

*“Any use of chlorine results in compounds that cause a wide range of ailments,”* says Joe Thornton, a Greenpeace researcher, who adds, *“Chlorine is simply not compatible with life. Once you create it, you can’t control it.”*<sup>23</sup>

There's no doubt that our nation's sewage treatment systems are polluting our drinking water sources with pathogens. As a result, chlorine is also being used to disinfect *the water we drink* as well as to disinfect discharges from wastewater treatment facilities. It is estimated that 79% of the U.S. population is exposed to chlorine.<sup>24</sup> According to a 1992 study, *chlorine is added to 75% of the nation's drinking water* and is linked to cancer. The results of the study suggested that at least 4,200 cases of bladder cancer and 6,500 cases of rectal cancer each year in the U.S. are associated with consumption of chlorinated drinking water.<sup>25</sup> This association is strongest in people who have been drinking chlorinated water for more than fifteen years.<sup>26</sup>

The U.S. Public Health Service reported that pregnant women who routinely drink or bathe in chlorinated tap water are at a greater risk of bearing premature or small babies, or babies with congenital defects.<sup>27</sup>

According to a spokesperson for the chlorine industry, 87% of water systems in the U.S. use free chlorines; 11% use chloramines. Chloramines are a combination of chlorine and ammonia. The chloramine treatment is becoming more widespread due to the health concerns over chlorine.<sup>28</sup> However, EPA scientists admit that we're pretty ignorant about the potential by-products of the chloramine process, which involves ozonation of the water prior to the addition of chloramine.<sup>29</sup>

According to a U.S. General Accounting Office report in 1992, consumers are poorly informed about potentially serious violations of drinking water standards. In a review of twenty water systems in six states, out of 157 drinking water quality violations, the public received a timely notice in only 17 of the cases.<sup>30</sup>

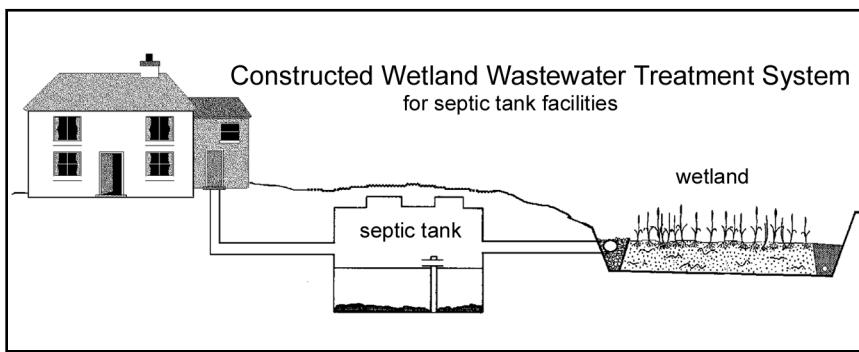
## ALTERNATIVE WASTEWATER TREATMENT SYSTEMS

New systems are being developed to purify wastewater. One popular experimental system today is the *constructed, or artificial wetlands system*, which diverts wastewater through an aquatic environment consisting of aquatic plants such as water hyacinths, bullrushes, duckweed, lilies and cattails. The plants act as marsh filters, and the microbes which thrive on their roots break down nitrogen and phosphorous compounds, as well as toxic chemicals. Although they don't break down heavy metals, the plants absorb them and they can then be harvested for incineration or landfilled.<sup>31</sup>

According to EPA officials, the emergence of constructed wetlands technology shows great potential as a cost-effective alternative to wastewater treatment. The wetlands method is said to be relatively affordable, energy-efficient, practical and effective. The treatment efficiency of properly constructed wetlands is said to compare well with conventional treatment systems.<sup>32</sup> Unfortunately, wetlands systems don't recover the agricultural resources available in humanure.

Another system uses solar-powered, greenhouse-like technology to treat wastewater. This system uses hundreds of species of bacteria, fungi, protozoa, snails, plants and fish, among other things, to produce advanced levels of wastewater treatment. These Solar Aquatics systems are also experimental, but appear hopeful.<sup>33</sup> Again, the agricultural resources of humanure are lost when using any disposal method or wastewater treatment technique instead of a humanure recycling method.

When a household humanure recycling method *is* used, however, and sewage is *not* being produced, most households will still be producing graywater. Graywater is the water that is used for washing, bathing, and laundry, and it must be dealt with in a responsible manner before draining into the environment. Most households produce



sewage (blackwater). Households which compost their humanure may produce no sewage at all — these households are prime candidates for *alternative* graywater systems. Such systems are discussed in Chapter 9.

### AGRICULTURAL USE OF SEWAGE SLUDGE

Now here's where a thoughtful person may ask, "Why not put sewage *sludge* back into the soil for agricultural purposes?"

One reason: government regulation. When I asked the supervisor of my local wastewater treatment plant if the one million gallons of sludge the plant produces each year, from a population of 8,000 people, was being applied to agricultural land, he said, "*It takes six months and five thousand dollars to get a permit for a land application. Another problem is that due to regulations, the sludge can't lie on the surface after it's applied, so it has to be plowed under shortly after application. When farmers get the right conditions to plow their fields, they plow them. They can't wait around for us, and we can't have sludge ready to go at plowing time.*" It may be just as well.

Problems associated with the agricultural use of sewage sludge include groundwater, soil and crop contamination with pathogens, heavy metals, nitrates, and toxic and carcinogenic organic compounds.<sup>34</sup> Sewage sludge is a lot more than organic agricultural material. It can contain DDT, PCBs, mercury and other heavy metals.<sup>35</sup> One scientist alleges that more than 20 million gallons of used motor oil are dumped into sewers every year in the United States.<sup>36</sup>

America's largest industrial facilities released over 550 million pounds of toxic pollutants into U.S. sewers in 1989 alone, according to the U.S. Public Interest Research Group. Between 1990 and 1994, an additional 450 million pounds of toxic chemicals were dumped into sewage treatment systems, although the actual levels of toxic discharges are said to be much higher than these.<sup>37</sup>

Of the top ten states responsible for toxic discharges to public sewers in 1991, Michigan took first prize with nearly 80 million pounds, followed in order by New Jersey, Illinois, California, Texas, Virginia, Ohio, Tennessee, Wisconsin and Pennsylvania (around 20 million pounds from PA).<sup>38</sup>

An interesting study on the agricultural use of sludge was done by a Mr. Purves in Scotland. He began applying sewage sludge at the rate of 60 tons per acre to a plot of land in 1971. After fifteen years of treating the soil with the sludge, he tested the vegetation

Table 5.1  
**BRAND NAMES OF SEWAGE SLUDGE  
 FERTILIZERS ONCE MARKETED**

<u>SOURCE CITY</u>	<u>NAME*</u>
Akron, OH .....	Akra-Soilite
Battle Creek, MI . . .	Battle Creek Plant Food
Boise, ID .....	B.I. Organic
Charlotte, NC .....	Humite & Turfood
Chicago, IL .....	Chicagro & Nitrogenic
Clearwater, FL .....	Clear-O-Sludge
Fond du Lac, WI . . .	Fond du Green
Grand Rapids, MI . . .	Rapidgro
Houston, TX .....	Hu-Actinlite
Indianapolis, IN .....	Indas
Madison, WI .....	Nitrohumus
Massillon, OH .....	Greengro
Milwaukee, WI .....	Milorganite
Oshkosh, WI .....	Oshkonite
Pasadena, CA .....	Nitrogenic
Racine, WI .....	Ramos
Rockford, IL .....	Nu-Vim
San Diego, CA .....	Nitro Gano
San Diego, CA .....	San-Diegonite
S. California .....	Sludgeon
Schenectady, NY .....	Orgro & Gro-hume
Toledo, OH .....	Tol-e-gro

\*Names are registered brand names.

Sources: Rodale, J. I. et al. (Eds.). (1960). *The Complete Book of Composting*. Rodale Books Inc.: Emmaus, PA. pp. 789, 790. and Collins, Gilbeart H., (1955). *Commercial Fertilizers - Their Sources and Use*. Fifth Edition. McGraw-Hill Book Co., New York

grown on the plot for heavy metals. On finding that the heavy metals (lead, copper, nickel, zinc and cadmium) had been taken up by the plants, he concluded, “Contamination of soils with a wide range of potentially toxic metals following application of sewage sludge is therefore virtually irreversible.”<sup>39</sup> In other words, the heavy metals don’t wash out of the soil, they enter the food chain, and may contaminate not only crops, but also grazing animals.<sup>40</sup>

Other studies have shown that heavy metals accumulate in the vegetable tissue of the plant to a much greater extent than in the fruits, roots, or tubers. Therefore, if one must grow food crops on soil fertilized with sewage sludge contaminated with heavy metals, one might be wise to produce carrots or potatoes instead of lettuce.<sup>41</sup> Guinea pigs experimentally fed with swiss chard grown on soil fertilized with sewage sludge showed no observable toxicological effects. However, their adrenals showed elevated levels of antimony, their kidneys had elevated levels of cadmium, there was elevated manganese in the liver and elevated tin in several other tissues.<sup>42</sup>

Estimated to contain 10 billion microorganisms per gram, sludge may contain many human pathogens.<sup>43</sup> “The fact that sewage sludge contains a large population of fecal coliforms renders it suspect as a potential vector of bacterial pathogens and a possible contaminant of soil, water and air, not to mention crops. Numerous investigations in different parts of the world have confirmed the presence of intestinal pathogenic bacteria and animal parasites in sewage, sludge, and fecal materials.”<sup>44</sup>

Because of their size and density, parasitic worm eggs settle

into and concentrate in sewage sludge at wastewater treatment facilities. One study indicated that roundworm eggs could be recovered from sludge at all stages of the wastewater treatment process, and that two-thirds of the samples examined had viable eggs.<sup>45</sup> Agricultural use of the sludge can therefore infect soil with 6,000-12,000 viable parasitic worm eggs per square meter, per year. These eggs can persist in some soils for five years or more.<sup>46</sup> Furthermore, *Salmonellae* bacteria in sewage sludge can remain viable on grassland for several weeks, thereby making it necessary to restrict grazing on pastureland after a sludge application. Beef tapeworm (*Taenia saginata*), which uses cattle as its intermediate host and humans as its final host, can also infect cattle that graze on pastureland fertilized with sludge. The tapeworm eggs can survive on sludged pasture for a full year.<sup>47</sup>

Another interesting study published in 1989 indicated that bacteria surviving in sewage sludge show a high level of resistance to antibiotics, especially penicillin. Because heavy metals are concentrated in sludge during the treatment process, the bacteria that survive in the sludge can obviously resist heavy metal poisoning. These same bacteria also show an inexplicable resistance to antibiotics, suggesting that somehow the resistance of the two environmental factors are related in the bacterial strains that survive. The implication is that sewage sludge selectively breeds antibiotic-resistant bacteria, which may enter the food chain if the agricultural use of the sludge becomes widespread. The results of the study indicated that more knowledge of antibiotic-resistant bacteria in sewage sludge should be acquired before sludge is disposed of on land.<sup>48</sup>

This poses somewhat of a problem. Collecting human excrement with wastewater and industrial pollutants seems to render the organic refuse incapable of being adequately sanitized. It becomes contaminated enough to be unfit for agricultural purposes. As a consequence, sewage sludge is not highly sought after as a soil additive. For example, the state of Texas sued the U.S. EPA in July of 1992 for failing to study environmental risks before approving the spreading of sewage sludge in west Texas. Sludge was being spread on 128,000 acres there by an Oklahoma firm, but the judge nevertheless refused to issue an injunction to stop the spreading.<sup>49</sup>

Now that ocean dumping of sludge has been stopped, where's it going to go? Researchers at Cornell University have suggested that sewage sludge can be disposed of by surface applications in forests. Their studies suggest that brief and intermittent applications of sludge to forestlands won't adversely affect wildlife, despite the

nitrates and heavy metals that are present in the sludge. They point out that the need to find ways to get rid of sludge is compounded by the fact that many landfills are expected to close and ocean dumping is now banned.

Under the Cornell model, one dry ton of sludge could be applied to an acre of forest each year.<sup>50</sup> New York state alone produces 370,000 tons of dry sludge per year, which would require 370,000 acres of forest each year for sludge disposal. Consider the fact that forty-nine other states produce 7.6 million dry tons of sludge. Then there's figuring out how to get the sludge into the forests and how to spread it around. With all this in mind, a guy has to stop and wonder — the woods used to be the only place left to get away from it all!

The problem of treating and dumping sludge isn't the only one. The costs of maintenance and upkeep of wastewater treatment plants is another. According to a report issued by the EPA in 1992, U.S. cities and towns need as much as \$110.6 billion over the next twenty years for enlarging, upgrading, and constructing wastewater treatment facilities.<sup>51</sup>

Ironically, when sludge is *composted*, it may help to keep heavy metals *out* of the food chain. According to a 1992 report, composted sludge lowered the uptake of lead in lettuce that had been deliberately planted in lead-contaminated soil. The lettuce grown in the contaminated soil which was amended with composted sludge had a 64% lower uptake of lead than lettuce planted in the same soil but without the compost. The composted soil also lowered lead uptake in spinach, beets and carrots by more than 50%.<sup>52</sup>

Some scientists claim that the composting process transforms heavy metals into benign materials. One such scientist who designs facilities that compost sewage sludge states, '*At the final product stage, these [heavy] metals actually become beneficial micro-nutrients and trace minerals that add to the productivity of soil. This principle is now finding acceptance in the scientific community of the U.S.A. and is known as biological transmutation, or also known as the Kervran-Effect.*' Other scientists scoff at such a notion.

Composted sewage sludge that is microbiologically active can also be used to detoxify areas contaminated with nuclear radiation or oil spills, according to researchers. Clearly, the composting of sewage sludge is a grossly underutilized alternative to landfill application, and it should be strongly promoted.<sup>53</sup>

Other scientists have shown that heavy metals in contaminated compost are *not* biologically transmuted, but are actually *concentrated*.

*trated* in the finished compost. This is most likely due to the fact that the compost mass shrinks considerably during the composting process, showing reductions of 70%, while the amount of metals remains the same. Some researchers have shown a decrease in the concentrations of *some* heavy metals and an increase in the concentrations of others, for reasons that are unclear. Others show a considerable decrease in the concentrations of heavy metals between the sludge and the finished compost. Results from various researchers “*are giving a confusing idea about the behavior of heavy metals during composting. No common pattern of behavior can be drawn between similar materials and the same metals . . .*”<sup>54</sup> However, metals concentrations in finished compost seem to be low enough that they are not considered to be a problem largely because metal-contaminated sludge is greatly diluted by other clean organic materials when composted.<sup>55</sup>

## GLOBAL SEWERS AND PET TURDS

Let’s assume that the whole world adopted the sewage philosophy we have in the United States: defecate into water and then treat the polluted water. What would that scenario be like? Well, for one thing it wouldn’t work. It takes between 1,000 and 2,000 tons of water at various stages in the process to flush one ton of humanure. In a world of just six billion people producing a conservative estimate of 1.2 million metric tons of human excrement daily, the amount of water required to flush it all would not be obtainable.<sup>56</sup> Considering the increasing landfill space that would be needed to dispose of the increasing amounts of sewage sludge, and the tons of toxic chemicals required to “sterilize” the wastewater, one can realize that this system of human waste disposal is far from sustainable and cannot serve the needs of humanity in the long term.

According to Barbara Ward, President of the International Institute for Environment and Development, “*Conventional ‘Western’ methods of waterborne sewerage are simply beyond the reach of most [of the world’s] communities. They are far too expensive. And they often demand a level of water use that local water resources cannot supply. If Western standards were made the norm, some \$200 billion alone [early 1980s] would have to be invested in sewerage to achieve the target of basic sanitation for all. Resources on this scale are simply not in sight.*”

To quote Lattee Fahm, “*In today’s world [1980], some 4.5 billion people produce excretal matters at about 5.5 million metric tons every twenty-four hours, close to two billion metric tons per year. [Humanity] now*

*occupies a time/growth dimension in which the world population doubles in thirty five years or less. In this new universe, there is only one viable and ecologically consistent solution to the body waste problems — the processing and application of [humanure] for its agronutrient content.”*<sup>57</sup> This sentiment is echoed by World Bank researchers, who state, “[I]t can be estimated that the backlog of over one billion people not now provided with water or sanitation service will grow, not decrease. It has also been estimated that most developing economies will be unable to finance water carriage waste disposal systems even if loan funds were available.”<sup>58</sup>

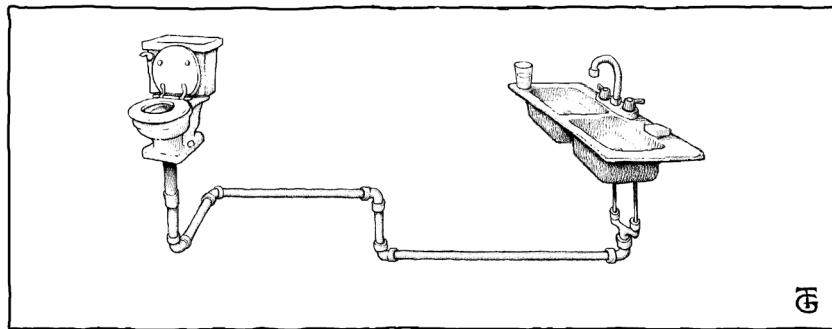
In other words, we have to understand that humanure is a natural substance, produced by a process vital to life (human digestion), originating from the earth in the form of food, and valuable as an organic refuse material that can be returned to the earth in order to produce more food for humans. That’s where composting comes in.

But hey, wait, let’s not rush to judgement. We forgot about incinerating our excrements. We can dry our turds out, then truck them to big incinerators and burn the hell out of them. That way, instead of having fecal pollution in our drinking water or forests, we can breathe it in our air. Unfortunately, burning sludge with other municipal waste produces emissions of particulate matter, sulfur dioxide, nitrogen oxides, carbon monoxide, lead, volatile hydrocarbons, acid gases, trace organic compounds and trace metals. The leftover ash has a high concentration of heavy metals, such as cadmium and lead.<sup>59</sup> Doesn’t sound so good if you live downwind, does it?

How about microwaving it? Don’t laugh, someone’s already invented the microwave toilet.<sup>60</sup> This just might be a good cure for hemorrhoids, too. But heck, let’s get serious and shoot it into outer space. Why not? It probably wouldn’t cost too much per turd after we’ve dried the stuff out. This could add a new meaning to the phrase “the Captain’s log.” Beam up another one, Scotty!

Better yet, we can dry our turds out, chlorinate them, get someone in Taiwan to make little plastic sunglasses for them, then we’ll sell them as Pet Turds! Now that’s an entrepreneurial solution, isn’t it? Any volunteer investors out there?





## COMPOSTING TOILETS AND SYSTEMS

Technically, a “composting toilet” is a toilet in which composting takes place. Usually, the composting chamber is located under the toilet. Other toilets are simply collection devices in which humanure is deposited, then removed to a separate composting location away from the toilet area. These toilets are components of “composting toilet systems,” rather than composting toilets, *per se*. They can also be called “compost toilets.”

Humanure composting toilets and systems can generally be divided into two categories based on the composting temperatures they generate. Some toilet systems produce thermophilic (hot) compost; others produce low-temperature compost. Most commercial and homemade composting toilets are low-temperature composting toilets, sometimes called “mouldering toilets.”

The most basic way to compost humanure is simply to collect it in a toilet receptacle and add it to a compost pile. The toilet acts only as a collection device, while the composting takes place at a separate location. Such a toilet requires little, if any, expense and can be constructed and operated by people of simple means in a wide range of cultures around the world. It is easy to create thermophilic (hot) compost with such a collection toilet. This type of toilet is discussed in detail in Chapter 8, “The Tao of Compost.”

The toilets of the future will also be collection devices rather than waste disposal devices. The collected organic material will be hauled away from homes, like municipal garbage is today, and composted under the responsibility of municipal authorities, perhaps

under contract with private sector composting facilities. Currently, other recyclable materials such as bottles and cans are collected from homes by municipalities; in some areas organic food materials are also collected and composted at centralized composting facilities. The day will come when the collected organic materials will include toilet materials.

In the meantime, homeowners who want to make compost rather than sewage must do so independently by either constructing a composting toilet of their own, buying a commercial composting toilet, or using a simple collection toilet with a separate composting bin. The option one chooses depends upon how much money one wants to spend, where one lives, and how much involvement one wants in the compost-making process.

A simple collection toilet with a separate compost bin is the least expensive, but tends to be limited to homes where an outdoor compost bin can be utilized. Such a toilet is only attractive to people who don't mind the regular job of emptying containers of compost onto a compost pile, and who are willing to responsibly manage the compost to prevent odor and to ensure appropriate composting conditions.

Homemade composting toilets, on the other hand, generally include a compost bin underneath the toilet and do not involve transporting humanure to a separate composting area. They may be less expensive than commercial composting toilets and they can be built to whatever size and capacity a household requires, allowing for some creativity in their design. They are usually permanent structures located under the dwelling in a crawl space or basement, but they can also be free-standing outdoor structures. The walls are typically made of a concrete material, and the toilets are most successful when properly managed. Such management includes the regular addition to the toilet contents of sufficient carbon-based bulking material, such as sawdust, peat moss, straw, hay or weeds. Homemade composting toilets generally do not require water or electricity.

Commercial composting toilets come in all shapes, types, sizes, and price ranges. They're usually made of fiberglass or plastic and consist of a composting chamber underneath the toilet seat. Some of them use water and some of them require electricity. Some require neither.

## COMPOSTING TOILETS MUST BE MANAGED

We have used flush toilets for so long that after we defecate we expect to simply pull a handle and walk away. Some think that composting toilets should behave in the same manner. However, flush toilets are *disposal* devices that create pollution and squander soil fertility. Composting toilets are recycling devices that should create no pollution and should recover the soil nutrients in human manure and urine. When you push a handle on a flush toilet, you're paying someone to dispose of your waste for you. Not only are you paying for the water, for the electricity and for the wastewater treatment costs, but you are also contributing to the environmental problems inherent in waste disposal. When you use a composting toilet, you are *getting* paid for the small amount of effort you expend in recycling your organic material. Your payment is in the form of compost. Composting toilets, therefore, require some management. You have to *do* something besides just pushing a handle and walking away.

The degree of your involvement will depend on the type of toilet you are using. In most cases, this involves simply adding some clean organic cover material such as peat moss, sawdust, rice hulls or leaf mould to the toilet after each use. Instead of flushing, you cover. Nevertheless, someone must take responsibility for the overall management of the toilet. This is usually the homeowner, or someone else who has volunteered for the task. Their job is simply to make sure sufficient cover materials are available and being used in the toilet. They must also add bulking materials to the toilet contents when needed, and make sure the toilet is not being used beyond its capacity, not becoming waterlogged, and not breeding flies. Remember that a composting toilet houses an organic mass with a high level of microscopic biodiversity. The contents are alive, and must be watched over and managed to ensure greatest success.

## FECOPHOBIA AND THE PATHOGEN ISSUE

The belief that humanure is unsafe for agricultural use is called *fecophobia*. People who are fecophobic can suffer from severe fecophobia or a relatively mild fecophobia, the mildest form being little more than a healthy concern about personal hygiene. Severe fecophobics do not want to use humanure for food growing, composted or not. They believe that it's dangerous and unwise to use such a material in their garden. Milder fecophobics may, however, compost

humanure and use the finished compost in horticultural applications. People who are not fecophobic may compost humanure and utilize it in their food garden.

It is well known that humanure contains the *potential* to harbor disease-causing microorganisms or *pathogens*. This potential is directly related to the state of health of the population which is producing the excrement. If a family is composting its own humanure, for example, and it is a healthy family, the danger in the production and use of the compost will be very low. If one is composting the humanure from orphanages in Haiti where intestinal parasites are endemic, then extra precautions must be taken to ensure maximum pathogen death. Compost temperatures must rise significantly above the temperature of the human body ( $37^{\circ}\text{C}$  or  $98.6^{\circ}\text{F}$ ) in order to begin eliminating disease-causing organisms, as human pathogens thrive at temperatures similar to that of their hosts. On the other hand, most pathogens only have a limited viability outside the human body, and given enough time, will die even in low-temperature compost.

Humanure is best rendered hygienically safe by thermophilic composting. To achieve this, humanure can simply be collected and deposited on an outdoor compost pile like any other compost material. Open-air, outdoor compost piles with good access are easily managed and offer a no-cost, odorless method to achieve the thermophilic composting of humanure. However, such a system does require the regular collection and cartage of the organic material to the compost pile, making it relatively labor-intensive when compared to low-temperature, stationary, homemade and commercial composting toilets.

Many people will use a composting toilet only if they do not have to do anything in any way related to the toilet contents. Therefore, most homemade and commercial composting toilets are comprised of large composting chambers under the toilet seat. The organic material is deposited directly into a composting chamber, and the contents are emptied only very occasionally.

Thermophilic conditions do not seem to be common in these toilets, for several reasons. For one, many commercial composting toilets are designed to *dehydrate* the organic material deposited in them. This dehydration is achieved by electrical fans which rob the organic mass of moisture *and* heat. Commercial toilets also often strive to reduce the *volume* of material collecting in the composting chamber (mostly by dehydration), in order to limit the frequency of emptying for the sake of the convenience of the user. Bulky air-trapping additions to the compost are not encouraged, although

these additions will encourage thermophilic composting. Yet, even passive, low-temperature composting will eventually yield a relatively pathogen-free compost after a period of time.

Low-temperature composting toilets include most commercial and many homemade units. According to current scientific evidence, a few months retention time in just about any composting toilet will result in the deaths of nearly all human pathogens (see Chapter 7). The most persistent pathogen seems to be the roundworm (*Ascaris lumbricoides*) and particularly the egg of the roundworm, which is protected by an outer covering which resists chemicals and adverse environmental conditions. Estimates of the survival time of *Ascaris* eggs in certain soil types under certain conditions are as high as ten years. Although the *Ascaris* eggs are readily destroyed by thermophilic composting, they may survive in conditions generated by a low-temperature toilet. This is why the compost resulting from such toilets is generally not recommended for garden use if it comes in contact with food crops.

People can become rather obsessive about this issue. One man who published a book on this topic wrote to me to say that a two year retention time in a low-temperature composting toilet is generally considered adequate for the destruction of *Ascaris* ova (eggs). He indicated that he would never consider using his own low-temperature compost until it had aged at least two years. I asked him if he was infected with roundworms. He said no. I asked him if anyone else was using his toilet. No. I asked him why he would think there could be roundworm eggs in his compost when he knew he didn't have roundworms in the first place? Sometimes common sense is not so common when issues of humanure are involved. This is similar to the phobic person who would never go to a movie theater because there may be someone in the theater who has tuberculosis and who may sneeze. Although this is a risk we all take, it's not likely to be a problem.

#### OWNER-BUILT COMPOSTING TOILETS

Owner-built composting toilets are in widespread use throughout the world since many people do not have the financial resources required to purchase commercially-produced toilets. Owner-built devices tend to be low-temperature composting toilets, although they can conceivably be thermophilic toilet systems if properly managed.

The objectives of any composting toilet should be to achieve

safe and sanitary treatment of fecal material, to conserve water, to function with a minimum of maintenance and energy consumption, to operate without unpleasant odors and to recycle humanure back to the soil.

The primary advantage of low-temperature toilets is the passive involvement of the user. The toilet collection area need not be entered into very often unless, perhaps, to rake the pile flat. The pile that collects in the chamber must be raked somewhat every few months, which can be done through a floor access door. The chamber is emptied only after nothing has been deposited in it for at least a year or two, although this time period may vary depending on the individual system used.

In order for this system to work well, each toilet must have a minimum of two chambers. Fecal material and urine are deposited into the first chamber until it's full, then the second chamber is used while the first ages. By the time the second side is full, the first should be ready to empty. It may take several years to fill a side, depending on its capacity and the number of users. In addition to feces, carbonaceous organic matter such as sawdust, as well as bulky vegetable matter such as straw and weeds, are regularly added to the chamber in use. A clean cover of such material is maintained over the compost at all times for odor prevention.

Some composting toilets involve the separation of urine from feces. This is done by urinating into a separate container or into a diversion device which causes the urine to collect separately from the feces. The reason for separating urine from feces is that the urine/feces blend contains too much nitrogen to allow for effective composting and the collected material can get too wet and odorous. Therefore, the urine is collected separately, reducing the nitrogen, the liquid content and the odor of the collected material.

An alternative method of achieving the same result which does not require the separation of urine from feces does exist. Organic material with too much nitrogen for effective composting (such as a urine/feces mixture) can be balanced by adding more carbon material such as sawdust, rather than by removing the urine. The added carbon material absorbs the excess liquid and will cover the refuse sufficiently to eliminate odor completely. This also sets the stage for thermophilic composting because of the carbon/nitrogen balancing.

One should first prime a composting toilet chamber before use by creating a "biological sponge," a thick layer of absorbent organ-

ic material in the bottom of the compost chamber to a depth of up to 50% of its capacity. Some suggest that the toilet can be filled to 100% of its capacity before beginning to be used, because if the material is loose (such as loose hay), it will compress under the weight of the added humanure. A bottom sponge may even consist of bales of hay or straw buried in sawdust. These materials absorb the excess urine as it is added to the toilet. Fecal material is covered after each use with materials such as sawdust, peat, leaf mould or rice hulls. A drain into a five gallon bucket (perhaps pre-filled with sawdust) will collect any leachate, which can simply be deposited back on the compost pile. Extra bulking materials such as straw, weeds, hay and food scraps are regularly added to the compost chamber to help oxygenate and feed the growing organic mass in order to promote thermophilic decomposition. Ventilation can be enhanced by utilizing a vertical pipe installed like a chimney, which will allow air to passively circulate into and out of the compost chamber.

Such systems will need to be custom-managed according to the circumstances of the individuals using them. Someone needs to keep an eye on the toilet chambers to make sure they're receiving enough bulking material. The deposits need to be flattened regularly so that they remain covered and odorless. Chutes that channel humanure from the toilet seat to the compost chamber must be cleaned regularly in order to prevent odors. When one compost chamber is filled, it must be rested while the other is filled. A close eye on the toilet contents will prevent waterlogging. Any leachate system must be monitored.

In short, any composting toilet will require some management. Remember that you are actively recycling organic material and that means you are doing something constructive. When you consider the value of the finished compost, you can also realize that every time you deposit into a composting toilet, it's as if you're putting money in the bank.

Homemade low-temperature composting toilets offer a method of composting humanure that is attractive to persons wanting a low-maintenance, low-cost, fairly passive approach to excrement recycling. Any effort which constructively returns organic refuse to the soil without polluting water or the environment certainly demands a high level of commendation.

## ASIAN COMPOSTING

It is well known that Asians have recycled humanure for centuries, possibly millennia. How did they do it? Historical information concerning the composting of humanure in Asia seems difficult to find. Rybczynski et al. state that composting was only introduced to China in a systematic way in the 1930s and that it wasn't until 1956 that composting toilets were used on a wide scale in Vietnam.<sup>1</sup> On the other hand, Franceys et al. tell us that composting "has been practiced by farmers and gardeners throughout the world for many centuries." They add that, "In China, the practice of composting [humanure] with crop residues has enabled the soil to support high population densities without loss of fertility for more than 4000 years."<sup>2</sup>

However, a book published in 1978 and translated directly from the original Chinese indicates that composting has not been a cultural practice in China until only recently. An agricultural report from the Province of Hopei, for example, states that the standardized management and hygienic disposal (i.e., composting) of excreta and urine was only initiated there in 1964. The composting techniques being developed at that time included the segregation of feces and urine, which were later "poured into a mixing tank and mixed well to form a dense fecal liquid" before piling on a compost heap. The compost was made of 25% human feces and urine, 25% livestock manure, 25% miscellaneous organic refuse and 25% soil.<sup>3</sup>

Two aerobic methods of composting were reported to be in widespread use in China, according to the 1978 report. The two methods are described as: 1) surface aerobic continuous composting; and 2) pit aerobic continuous composting. The surface method involves constructing a compost pile around an internal framework of bamboo, approximately nine feet by nine feet by three feet high (3m x 3m x 1m). Compost ingredients include fecal material (both human and non-human), organic refuse and soil. The bamboo poles are removed after the compost pile has been constructed — the resultant holes allowing for the penetration of air into this rather large pile of refuse. The pile is then covered with earth or an earth/horse manure mix, and left to decompose for 20 to 30 days, after which the composted material is used in agriculture.

The pit method involves constructing compost pits five feet wide and four feet deep by various lengths, and digging channels in the floor of the pits. The channels (one lengthwise and two widthwise) are covered with coarse organic material such as millet stalks.

A bamboo pole is then placed vertically along the walls of the pit at the end of each channel. The pit is then filled with organic refuse and covered with earth, and the bamboo poles are removed to allow for air circulation.<sup>4</sup>

A report from a hygienic committee of the Province of Shantung provides us with additional information on Chinese composting.<sup>5</sup> The report lists three traditional methods used in that province for the recycling of humanure:

1) Drying — "Drying has been the most common method of treating human excrement and urine for years." It is a method that causes a significant loss of nitrogen;

2) Using it raw, a method that is known to allow pathogen transmission; and

3) "Connecting the household pit privy to the pig pen . . . a method that has been used for centuries." This is an unsanitary method in which the excrement was simply eaten by a pig.

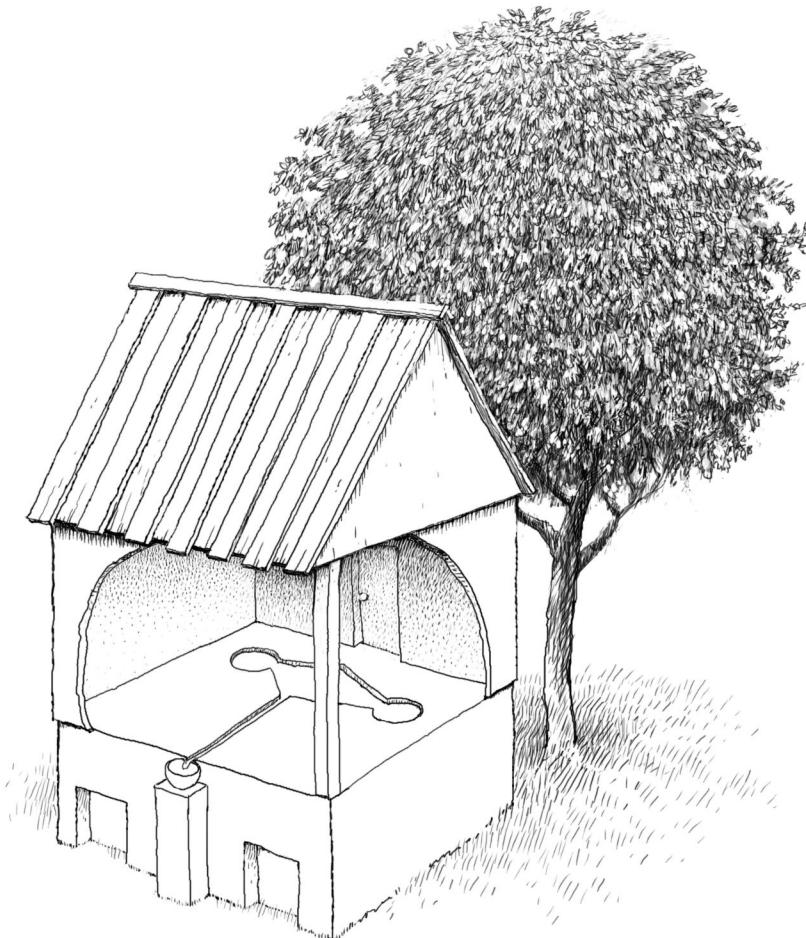
No mention is made whatsoever of composting being a traditional method used by the Chinese for recycling humanure. On the contrary, all indications were that the Chinese government in the 1960s was, at that time, attempting to establish composting as preferable to the three traditional recycling methods listed above, mainly because the three methods were hygienically unsafe, while composting, when properly managed, would destroy pathogens in humanure while preserving agriculturally valuable nutrients. This report also indicated that soil was being used as an ingredient in the compost, or, to quote directly, "Generally, it is adequate to combine 40-50% of excreta and urine with 50-60% of polluted soil and weeds."

For further information on Asian composting, I must defer to Rybczynski et al., whose World Bank research on low-cost options for sanitation considered over 20,000 references and reviewed approximately 1,200 documents. Their review of Asian composting is brief, but includes the following information, which I have condensed:

There are no reports of composting privys or toilets being used on a wide scale until the 1950s, when the Democratic Republic of Vietnam initiated a five-year plan of rural hygiene and a large number of anaerobic composting toilets were built. These toilets, known as the Vietnamese Double Vault, consisted of two above ground water-tight tanks, or vaults, for the collection of humanure. For a family of five to ten people, each vault was required to be 1.2 m wide, 0.7 m high and 1.7 m long (approximately 4 feet wide by 28 inches high and 5 feet, 7 inches long). One tank is used until full and

left to decompose while the other tank is used. The use of this sort of composting toilet requires the segregation of urine, which is diverted to a separate receptacle through a groove on the floor of the toilet. Fecal material is collected in the tank and covered with soil, where it anaerobically decomposes. Kitchen ashes are added to the fecal material for the purpose of reducing odor.

Eighty-five percent of intestinal worm eggs, one of the most persistently viable forms of human pathogens, were found to be destroyed after a two-month composting period in this system. However, according to Vietnamese health authorities, forty-five days



Vietnamese Double Vault

in a sealed vault is adequate for the complete destruction of all bacteria and intestinal parasites (presumably they mean pathogenic bacteria). Compost from such latrines is reported to increase crop yields by 10-25% in comparison to the use of raw humanure. The success of the Vietnamese Double Vault required "long and persistent health education programs."<sup>6</sup>

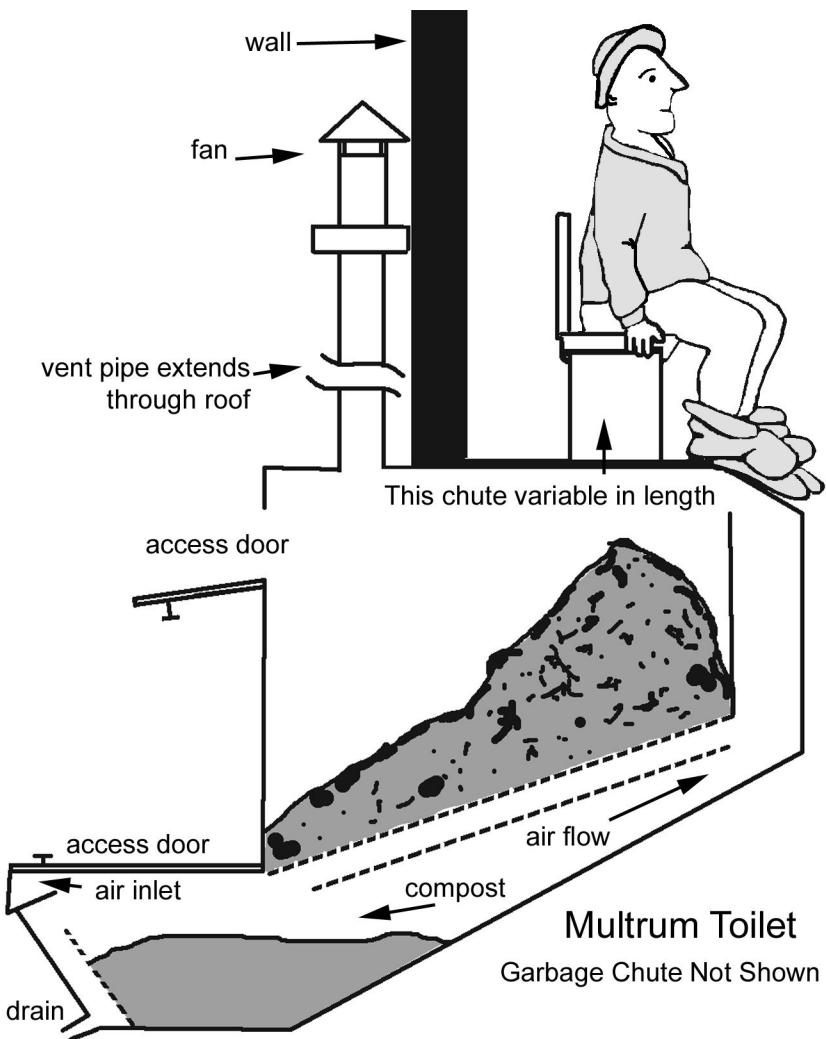
When the Vietnamese Double Vault composting toilet system was exported to Mexico and Central America, the result was "overwhelmingly positive," according to one source, who adds, "*Properly managed, there is no smell and no fly breeding in these toilets. They seem to work particularly well in the dry climate of the Mexican highlands. Where the system has failed because of wetness in the processing chamber, odours, and/or fly breeding, it was usually due to non-existent, weak, or bungled information, training and follow-up.*"<sup>7</sup> A lack of training and a poor understanding of the composting processes can cause any humanure composting system to become problematic. Conversely, complete information and an educated interest can ensure the success of humanure composting systems.

Another anaerobic double-vault composting toilet used in Vietnam includes using both fecal material and urine. In this system, the bottoms of the vaults are perforated to allow drainage, and urine is filtered through limestone to neutralize acidity. Other organic refuse is also added to the vaults, and ventilation is provided via a pipe.

In India, the composting of organic refuse and humanure is advocated by the government. A study of such compost prepared in pits in the 1950s showed that intestinal worm parasites and pathogenic bacteria were completely eliminated in three months. The destruction of pathogens in the compost was attributed to the maintenance of a temperature of about 40°C (104°F) for a period of 10-15 days. However, it was also concluded that the compost pits had to be properly constructed and managed, and the compost not removed until fully "ripe," in order to achieve the satisfactory destruction of human pathogens. If done properly, it is reported that "there is very little hygienic risk involved in the use and handling of [humanure] compost for agricultural purposes."<sup>8</sup>

## COMMERCIAL COMPOSTING TOILETS

Commercial composting toilets have been popular in Scandinavia for some time; at least twenty-one different composting toilets were on the market in Norway alone in 1975.<sup>9</sup> One of the most popular types of commercially available composting toilets in the United States today is the multrum toilet, invented by a Swedish engineer and first put into production in 1964. Fecal material and urine are deposited together into a single chamber with a double bottom. The decomposition takes place over a period of years, and the finished compost gradually falls down to the very bottom of the toilet



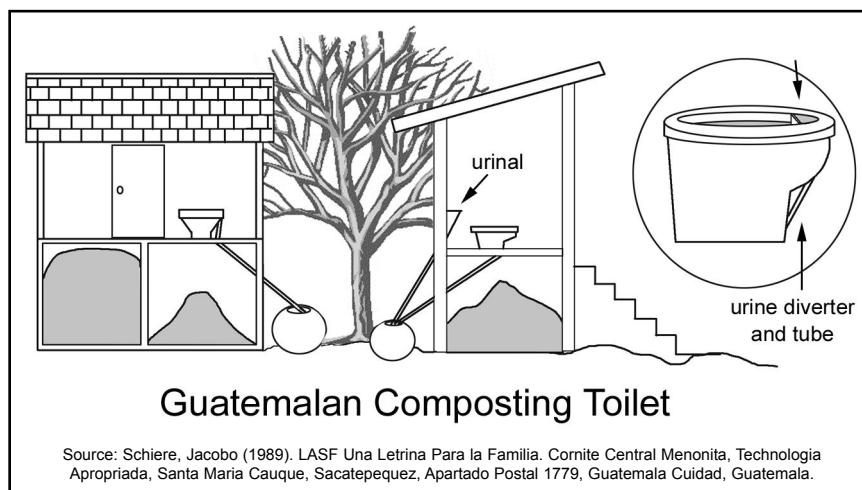
chamber where it can be removed. Again, the decomposition temperatures remain cool, not usually climbing above 32°C (90°F). Therefore, it is recommended that the finished compost be buried under one foot of soil or used in an ornamental garden.<sup>10</sup>

Because no water is used or required during the operation of this toilet, human excrement is kept out of water supplies. According to one report, a single person using a Clivus (pronounced Clee-vus) Multrum will produce 40 kg (88 lbs) of compost per year while refraining from polluting 25,000 liters (6,604 gallons) of water annually.<sup>11</sup> The finished compost can be used as a soil additive where the compost will not come in contact with food crops.

A 1977 report, issued by Clivus Multrum USA, analyzed the nutrient content in finished compost from seven Clivus Multrum toilets which had been in use for 4 to 14 years. The compost averaged 58% organic matter, with 2.4% nitrogen, 3.6% phosphorous, and 3.9% potassium, reportedly higher than composted sewage sludge, municipal compost or ordinary garden compost. Suitable concentrations of trace nutrients were also found. Toxic metals were found to exist in concentrations far below recommended safe levels.<sup>12</sup>

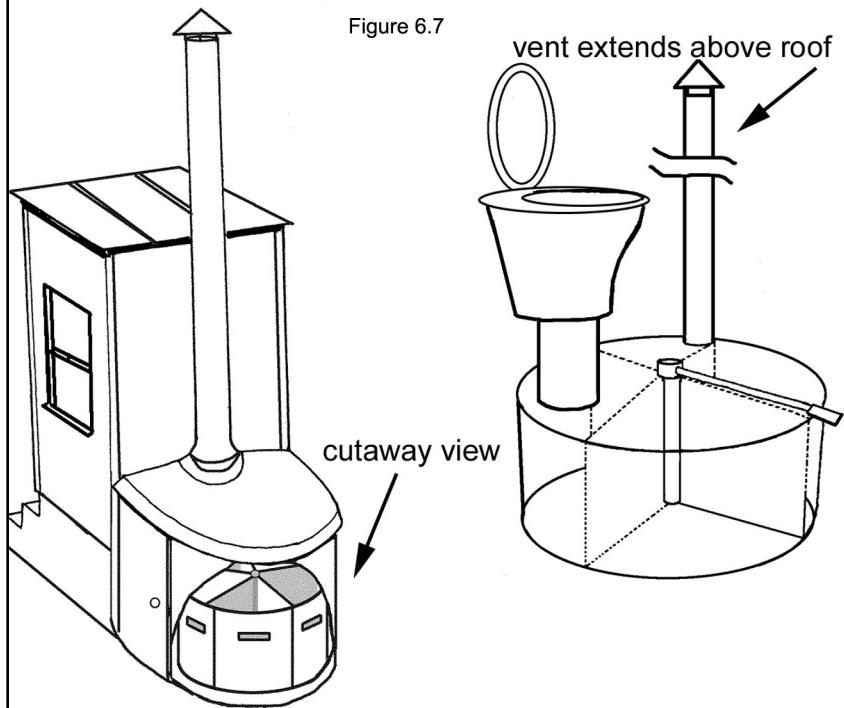
If a multrum toilet is managed properly, it should be odor and worry-free. As always, a good understanding of the basic concepts of composting helps anyone who wishes to use a composting toilet. Nevertheless, the multrum toilets, when used properly, should provide a suitable alternative to flush toilets for people who want to stop defecating in their drinking water. You can probably grow a heck of a rose garden with the compost, too.

Inexpensive versions of multrum toilets were introduced into



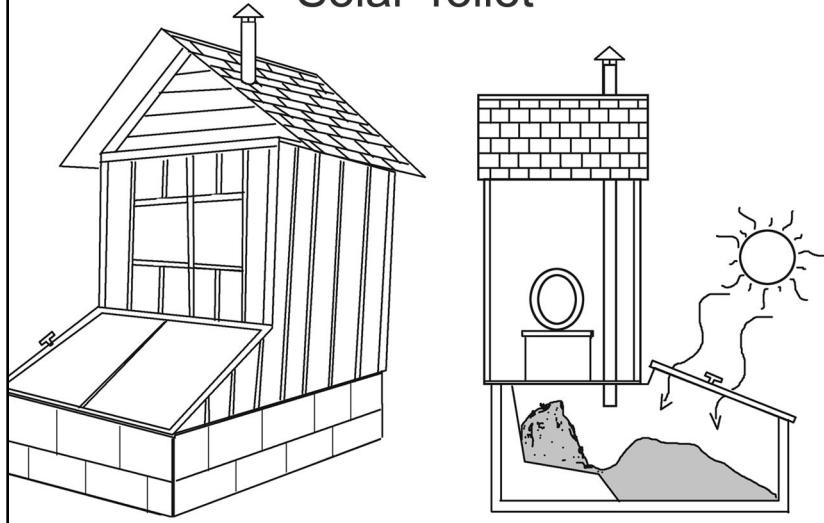
## Carousel Style Composting Toilet

Figure 6.7



Source: Winblad (ed.) 1998.  
Ecological Sanitation

## Solar Toilet



the Philippines, Argentina, Botswana and Tanzania, but were not successful. According to one source, "*Compost units I inspected in Africa were the most unpleasant and foul-smelling household latrines I have experienced. The trouble was that the mixture of excreta and vegetable matter was too wet, and insufficient vegetable matter was added, especially during the dry season.*"<sup>13</sup> Poor management and a lack of understanding of how composting works may create problems with any compost toilet. Too much liquid will create anaerobic conditions with consequent odors. The aerobic nature of the organic mass can be improved by the regular addition of carbonaceous bulking materials. Compost toilets are not pit latrines. You cannot just defecate in a hole and walk away. If you do, your nose will soon let you know that you're doing something wrong.

Besides the Scandinavian multrum toilets, a variety of other composting toilets are available on the market today. Some cost upwards of \$10,000 or more and can be equipped with insulated tanks, conveyers, motor-driven agitators, pumps, sprayers, and exhaust fans.<sup>15</sup>

According to a composting toilet manufacturer, waterless composting toilets can reduce household water consumption by 40,000 gallons (151,423 liters) per year.<sup>16</sup> This is significant when one considers that only 3% of the Earth's water is not salt water, and two-thirds of the freshwater is locked up in ice. That means that less than one percent of the Earth's water is available as drinking water. Why shit in it?

#### COMPOST TESTING LABS

**WOODS END AGRICULTURAL INSTITUTE, INC.** — PO Box 297, Mt. Vernon, ME 04352 USA; Ph: 207-293-2457 or 800 451 0337; FAX: 207-293-2488; email: [compost@woodsend.org](mailto:compost@woodsend.org); website: [woodsend.org](http://woodsend.org); Ascaris and coliform testing as well as full nutrient tests. Sells the Solvita(R) Maturity Test Kit which is now approved in CA, CT, IL, MA, ME, NJ, NM, OH, TX, and WA. Has developed a soil-respiration test kit that is approved by the USDA for soil quality investigations.

**WOODS END EUROPE** — AUC - Agrar und Umwelt-Consult GmbH; Augustastrasse 9 D-53173 Bonn, Germany; Ph: 049 0228 343246; FAX: 049 0228 343237; Officially certified for pathogen survival testing. Sells the Solvita(R) Maturity Test Kit which is now approved in CA, CT, IL, MA, ME, NJ, NM, OH, TX, and WA.

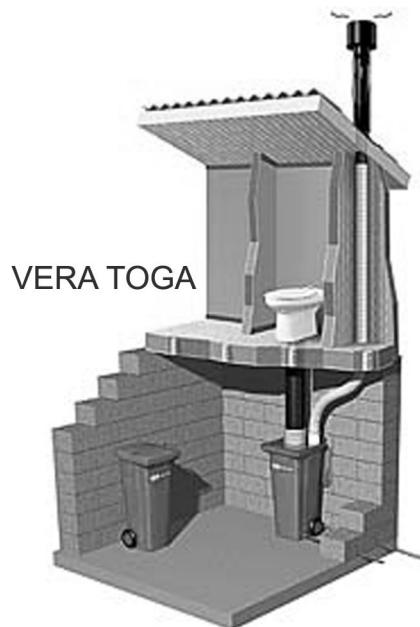
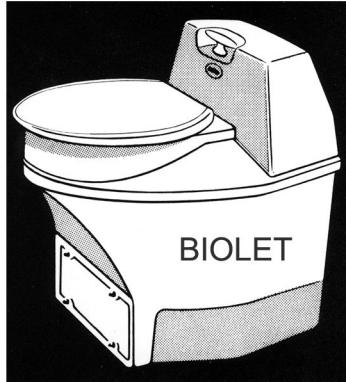
**CONTROL LAB, INC.** — 42 Hangar Way, Watsonville, CA 95076 USA; Ph: 831-724-5422; Fax: 831-724-3188

#### COMPOST THERMOMETERS

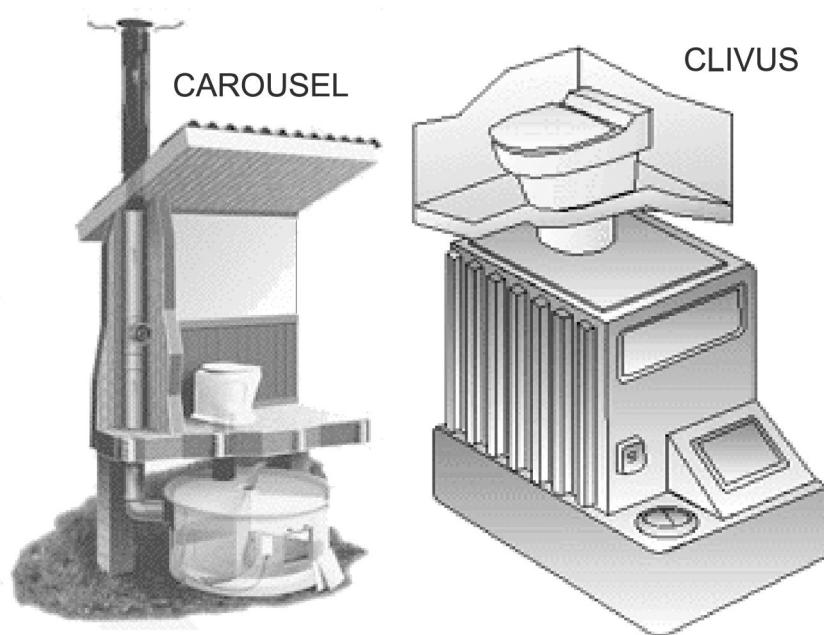
**REOTEMP** — 10656 Roselle Street, San Diego, CA 92121 USA; Ph: 858-784-0710 (Toll free: 800-648-7737); Fax: 858-784-0720; email: [reotemp@reotemp.com](mailto:reotemp@reotemp.com); website: [www.reotemp.com](http://www.reotemp.com)

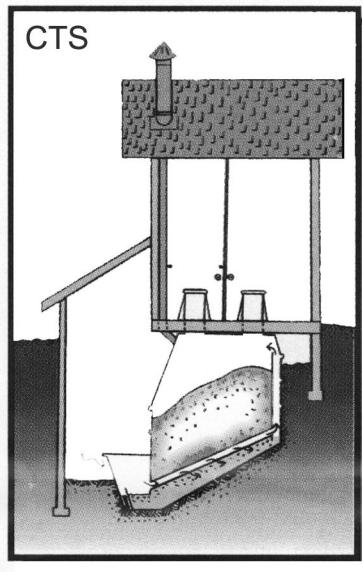
## A Sampler of Commercial Composting Toilets and Systems

For more information about these and other composting toilets, search the internet.

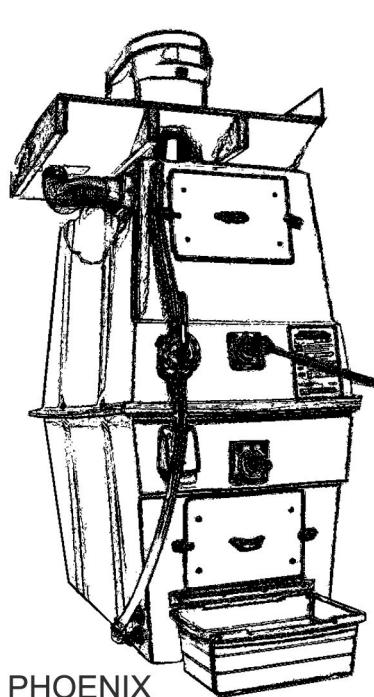


Clockwise from top left: Biolet,  
Vera Toga, Clivus, Carousel.

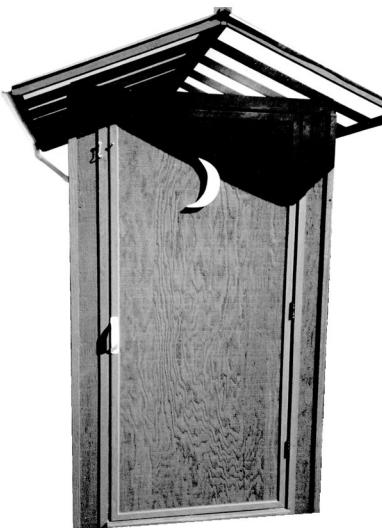




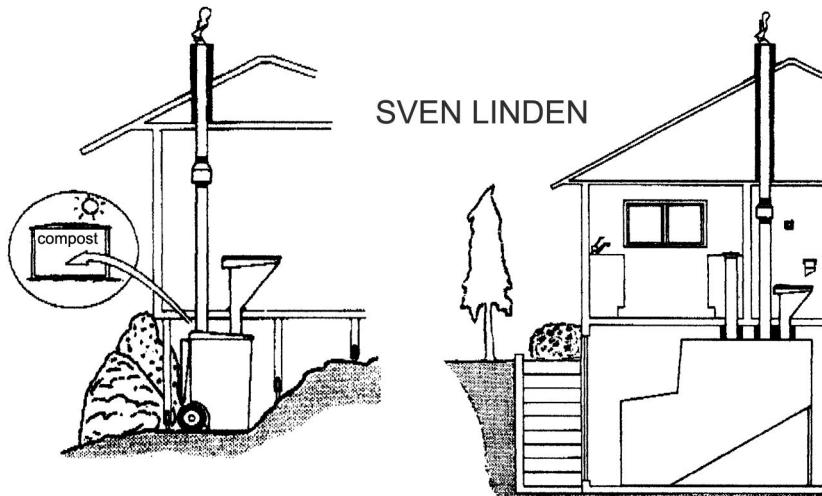
ENVIROLET



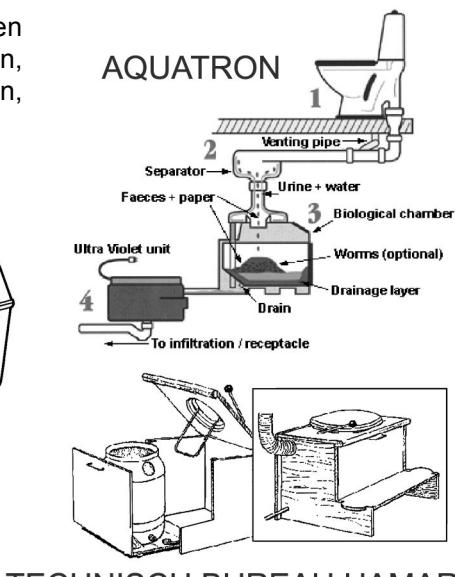
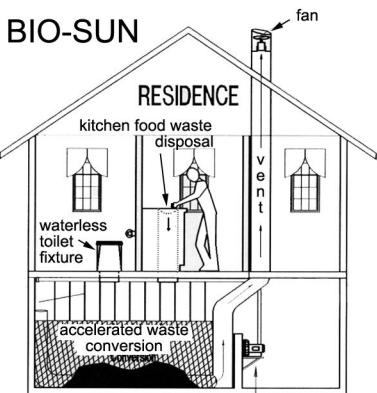
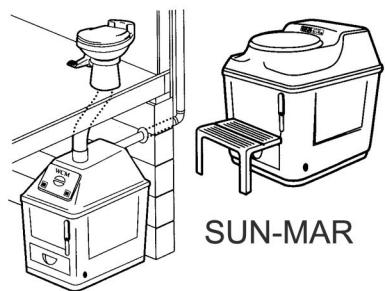
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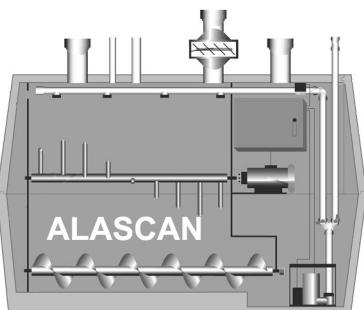
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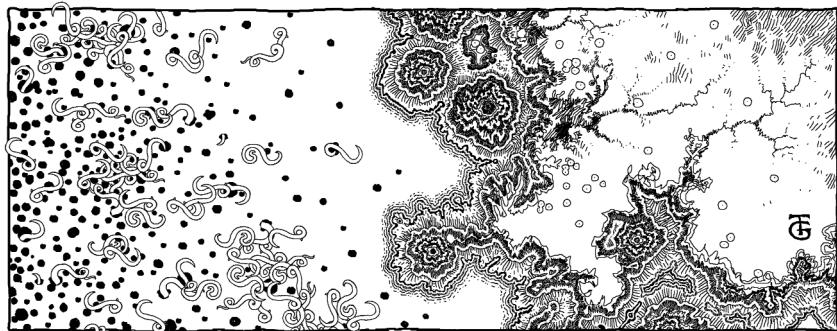


Clockwise from top left: Sven Linden, Sven Linden, Aquatron, Dutch Hamar, Alascan, Bio-Sun, Sun-Mar.



TECHNISCH BUREAU HAMAR





## WORMS AND DISEASE

I well remember in early 1979 when I first informed a friend that I intended to compost my own manure and grow my own food with it. “*Oh my God, you can’t do that!*” she cried.

“Why not?”

“Worms and disease!”

Of course.

A young English couple was visiting me one summer after I had been composting humanure for about six years. One evening, as dinner was being prepared, the couple suddenly understood the horrible reality of their situation: the food they were about to eat was *recycled human shit*. When this fact abruptly dawned upon them, it seemed to set off an instinctive alarm, possibly inherited directly from Queen Victoria. “*We don’t want to eat shit!*” they informed me, rather distressed (that’s an exact quote), as if in preparing dinner I had simply set a steaming turd on a plate in front of them with a knife, fork and napkin.

*Fecophobia* is alive and well and running rampant. One common misconception is that fecal material, when composted, remains fecal material. *It does not*. Humanure comes from the earth, and through the miraculous process of composting, is converted back into earth. When the composting process is finished, the end product is humus, not crap, and it is useful in growing food. My friends didn’t understand this and despite my attempts to clarify the matter for their benefit, they chose to cling to their misconceptions. Apparently, some fecophobes will always remain fecophobes.

Allow me to make a radical suggestion: humanure is not dangerous. More specifically, it is not any more dangerous than the body from which it is excreted. The danger lies in what we *do* with humanure, not in the material itself. To use an analogy, a glass jar is not dangerous either. However, if we smash it on the kitchen floor and walk on it with bare feet, we will be harmed. If we use a glass jar improperly and dangerously, we will suffer for it, but that's no reason to condemn glass jars. When we discard humanure as a waste material and pollute our soil and water supplies with it, we are using it improperly, and *that* is where the danger lies. When we constructively recycle humanure by composting, it enriches our soil, and, like a glass jar, actually makes life easier for us.

Not all cultures think of human excrement in a negative way. For example, swear-words meaning excrement do not seem to exist in the Chinese language. The Tokyo bureau chief for the New York Times explains why: “*I realized why people [in China] did not use words for excrement in a negative way. Traditionally, there was nothing more valuable to a peasant than [humanure].*”<sup>1</sup> Calling someone a “humanure head” just doesn’t sound like an insult. “Humanure for brains” doesn’t work either. If you told someone they were “full of humanure,” they’d probably agree with you. “Shit,” on the other hand, is a substance that is widely denounced and has a long history of excoriation in the western world. Our ancestor’s historical failure to responsibly recycle the substance caused monumental public health headaches. Consequently, the attitude that humanure *itself* is terribly dangerous has been embraced and promulgated up to the present day.

For example, a recently published book on the topic of recycling “human waste” begins with the following disclaimer: “*Recycling human waste can be extremely dangerous to your health, the health of your community and the health of the soil. Because of the current limits to general public knowledge, [we] strongly discourage the recycling of human waste on an individual or community basis at this time and cannot assume responsibility for the results that occur from practicing any of the methods described in this publication.*” The author adds, “*Before experimenting, obtain permission from your local health authority since the health risks are great.*” The author then elaborates upon a human “waste” composting methodology which includes segregating urine from feces, collecting the manure in 30 gallon plastic containers, and using straw rather than sawdust as a cover material in the toilet.<sup>2</sup> All three of these procedures are ones I would discourage based on my 26 years of humanure composting experience — there is no need to go to the bother of

segregating urine; a 30 gallon container is much too big and heavy to be able to handle easily; and *sawmill* sawdust does, in fact, work beautifully in a composting toilet, much better than straw. These issues will be discussed in the next chapter.

I had to ask myself why an author writing a book on recycling humanure would “strongly discourage the recycling of human waste,” which seems counterproductive, to say the least. If I didn’t already know that recycling humanure was easy and simple, I might be totally petrified at the thought of attempting such an “extremely dangerous” undertaking after reading that book. And the last thing anyone wants to do is get the local health authorities involved. If there is anyone who knows nothing about composting humanure, it’s probably the local health authority, who receives no such training.

The “Bio-Dynamic” agricultural movement, founded by Dr. Rudolf Steiner, provides another example of fecophobia. Dr. Steiner has quite some following around the world and many of his teachings are followed almost religiously by his disciples. The Austrian scientist and spiritual leader had his own opinions about the recycling of humanure, based on intuition rather than on experience or science. He insisted that humanure must only be used to fertilize soil to grow plants to feed animals *other* than humans. The manure from *those* animals can then be used to fertilize soil to grow plants for human consumption. According to Steiner, humans must *never* get any closer to a direct human nutrient cycle than that. Otherwise, they will suffer “brain damage and nervous disorders.” Steiner further warned against using “lavatory fluid,” including human urine, which “should never be used as a fertilizer, no matter how well-processed or aged it is.”<sup>3</sup> Steiner, quite frankly, was ill-informed, incorrect, and fecophobic, and that fecophobia has no doubt rubbed off on some of his followers.

History is rife with humanure misconceptions. At one time, doctors insisted that human excrement should be an important and necessary part of one’s personal environment. They argued that, “*Fatal illness may result from not allowing a certain amount of filth to remain in [street] gutters to attract those putrescent particles of disease which are ever present in the air.*” At that time, toilet contents were simply dumped in the street. Doctors believed that the germs in the air would be drawn to the filth in the street and therefore away from people. This line of reasoning so influenced the population that many homeowners built their outhouses attached to their kitchens in order to keep their food germ-free and wholesome.<sup>4</sup> The results were just

the opposite — flies made frequent trips between the toilet contents and the food table.

By the early 1900s, the U.S. government was condemning the use of humanure for agricultural purposes, warning of dire consequences, including death, to those who would dare to do otherwise. A 1928 U.S. Department of Agriculture bulletin made the risks crystal clear: *“Any spittoon, slop pail, sink drain, urinal, privy, cesspool, sewage tank, or sewage distribution field is a potential danger. A bit of spit, urine, or feces the size of a pin head may contain many hundred germs, all invisible to the naked eye and each one capable of producing disease. These discharges should be kept away from the food and drink of [humans] and animals. From specific germs that may be carried in sewage at any time, there may result typhoid fever, tuberculosis, cholera, dysentery, diarrhea, and other dangerous ailments, and it is probable that other maladies may be traced to human waste. From certain animal parasites or their eggs that may be carried in sewage there may result intestinal worms, of which the more common are the hookworm, roundworm, whipworm, eelworm, tape-worm, and seat worm.”*

*Disease germs are carried by many agencies and unsuspectingly received by devious routes into the human body. Infection may come from the swirling dust of the railway roadbed, from contact with transitory or chronic carriers of disease, from green truck [vegetables] grown in gardens fertilized with night soil or sewage, from food prepared or touched by unclean hands or visited by flies or vermin, from milk handled by sick or careless dairymen, from milk cans or utensils washed with contaminated water, or from cisterns, wells, springs, reservoirs, irrigation ditches, brooks, or lakes receiving the surface wash or the underground drainage from sewage-polluted soil.”*

The bulletin continues, “*In September and October, 1899, 63 cases of typhoid fever, resulting in five deaths, occurred at the Northampton (Mass.) insane hospital. This epidemic was conclusively traced to celery, which was eaten freely in August and was grown and banked in a plot that had been fertilized in the late winter or early spring with the solid residue and scrapings from a sewage filter bed situated on the hospital grounds.”*

And to drive home the point that human waste is highly dangerous, the bulletin adds, “*Probably no epidemic in American history better illustrates the dire results that may follow one thoughtless act than the outbreak of typhoid fever at Plymouth, Pa., in 1885. In January and February of that year the night discharges of one typhoid fever patient were thrown out upon the snow near his home. These, carried by spring thaws into the public water supply, caused an epidemic running from April to*

*September. In a total population of about 8,000, 1,104 persons were attacked by the disease and 114 died.”*

The U.S. government bulletin insisted that the use of human excrement as fertilizer was both “dangerous” and “disgusting.” It warned that, *“under no circumstances should such wastes be used on land devoted to celery, lettuce, radishes, cucumbers, cabbages, tomatoes, melons, or other vegetables, berries, or low-growing fruits that are eaten raw. Disease germs or particles of soil containing such germs may adhere to the skins of vegetables or fruits and infect the eater.”* The bulletin summed it up by stating, *“Never use [human] waste to fertilize or irrigate vegetable gardens.”* The fear of human excrement was so severe it was advised that the contents of bucket toilets be burned, boiled, or chemically disinfected, then buried in a trench.<sup>5</sup>

This degree of fecophobia, fostered and spread by government authorities and others who knew of no constructive alternatives to waste disposal, still maintains a firm grip on the western psyche. It may take a long time to eliminate. A more constructive attitude is displayed by scientists with a broader knowledge of the subject of recycling humanure for agricultural purposes. They realize that the benefits of proper humanure recycling “far outweigh any disadvantages from the health point of view.”<sup>6</sup>

## THE HUNZAS

It’s already been mentioned that entire civilizations have recycled humanure for thousands of years. That should provide a fairly convincing testimony about the usefulness of humanure as an agricultural resource. Many people have heard of the “Healthy Hunzas,” a people in what is now a part of Pakistan who reside among the Himalayan peaks, and routinely live to be 120 years old. The Hunzas gained fame in the United States during the 1960s health food era when several books were written about the fantastic longevity of this ancient people. Their extraordinary health has been attributed to the quality of their overall lifestyle, including the quality of the natural food they eat and the soil it’s grown on. Few people, however, realize that the Hunzas also compost their humanure and use it to grow their food. They’re said to have virtually no disease, no cancer, no heart or intestinal trouble, and they regularly live to be over a hundred years old while *“singing, dancing and making love all the way to the grave.”*

According to Tompkins (1989), *“In their manuring, the*

*Hunzakuts return everything they can to the soil: all vegetable parts and pieces that will not serve as food for humans or beast, including such fallen leaves as the cattle will not eat, mixed with their own seasoned excrement [emphasis mine], plus dung and urine from their barns. Like their Chinese neighbors, the Hunzakuts save their own manure in special underground vats, clear of any contaminable streams, there to be seasoned for a good six months. Everything that once had life is given new to life through loving hands.”<sup>7</sup>*

Sir Albert Howard wrote in 1947, “*The Hunzas are described as far surpassing in health and strength the inhabitants of most other countries; a Hunza can walk across the mountains to Gilgit sixty miles away, transact his business, and return forthwith without feeling unduly fatigued.*” Sir Howard maintains that this is illustrative of the vital connection between a sound agriculture and good health, insisting that the Hunzas have evolved a system of farming which is perfect. He adds, “*To provide the essential humus, every kind of waste [sic], vegetable, animal and human, is mixed and decayed together by the cultivators and incorporated into the soil; the law of return is obeyed, the unseen part of the revolution of the great Wheel is faithfully accomplished.*”<sup>8</sup> Sir Howard’s view is that soil fertility is the real basis of public health.

A medical professional associated with the Hunzas claimed, “*During the period of my association with these people I never saw a case of asthenic dyspepsia, of gastric or duodenal ulcer, of appendicitis, of mucous colitis, of cancer . . . Among these people the abdomen over-sensitive to nerve impressions, to fatigue, anxiety, or cold was unknown. Indeed their buoyant abdominal health has, since my return to the West, provided a remarkable contrast with the dyspeptic and colonic lamentations of our highly civilized communities.*”

Sir Howard adds, “*The remarkable health of these people is one of the consequences of their agriculture, in which the law of return is scrupulously obeyed. All their vegetable, animal and human wastes [sic] are carefully returned to the soil of the irrigated terraces which produce the grain, fruit, and vegetables which feed them.*”<sup>9</sup>

The Hunzas composted their organic material, thereby recycling it. This actually enhanced their personal health and the health of their community. The U.S. Department of Agriculture was apparently unaware of the effective natural process of composting in 1928 when they described the recycling of humanure as “dangerous and disgusting.” No doubt the USDA would have confused the Hunzas, who had for centuries safely and constructively engaged in such recycling.

## PATHOGENS\*

Clearly, even the primitive composting of humanure for agricultural purposes does not necessarily pose a threat to human health, as evidenced by the Hunzas. Yet, fecal *contamination* of the environment certainly *can* pose a threat to human health. Feces can harbor a host of disease organisms which can contaminate the environment to infect innocent people when human excrement is discarded as a waste material. In fact, even a healthy person apparently free of disease can pass potentially dangerous pathogens through their fecal material, simply by being a carrier. The World Health Organization estimates that 80% of all diseases are related to inadequate sanitation and polluted water, and that half of the world's hospital beds are occupied by patients who suffer from water-related diseases.<sup>11</sup> As such, the composting of humanure would certainly seem like a worthwhile undertaking worldwide.

The following information is not meant to be alarming. It's included for the sake of thoroughness, and to illustrate the need to *compost* humanure, rather than to try to use it raw for agricultural purposes. When the composting process is side-stepped and pathogenic waste is dispersed into the environment, various diseases and worms can infect the population living in the contaminated area. This fact has been widely documented.

For example, consider the following quote from Jervis (1990): “*The use of night soil [raw human fecal material and urine] as fertilizer is not without its health hazards. Hepatitis B is prevalent in Dacaiyuan [China], as it is in the rest of China. Some effort is being made to chemically treat [humanure] or at least to mix it with other ingredients before it is applied to the fields. But chemicals are expensive, and old ways die hard. Night soil is one reason why urban Chinese are so scrupulous about peeling fruit, and why raw vegetables are not part of the diet. Negative features aside, one has only to look at satellite photos of the green belt that surrounds China's cities to understand the value of night soil.*”<sup>12</sup>

On the other hand, “worms and disease” are not spread by properly prepared compost, nor by healthy people. There is no reason to believe that the manure of a healthy person is dangerous unless left to accumulate, pollute water with intestinal bacteria, or breed flies and/or rats, all of which are the results of negligence or bad custom-

\*Much of the information in this section is adapted from *Appropriate Technology for Water Supply and Sanitation*, by Feachem et al., World Bank, 1980.<sup>10</sup> This comprehensive work cites 394 references from throughout the world, and was carried out as part of the World Bank's research project on appropriate technology for water supply and sanitation.

Table 7.1  
**POTENTIAL PATHOGENS IN URINE**

Healthy urine on its way out of the human body may contain up to 1,000 bacteria, of several types, per milliliter. More than 100,000 bacteria of a single type per milliliter signals a urinary tract infection. Infected individuals will pass pathogens in the urine that may include:

<b>Bacteria</b>	<b>Disease</b>
<i>Salmonella typhi</i> . . . . .	.Typhoid
<i>Salmonella paratyphi</i> . . . . .	.Paratyphoid fever
<i>Leptospira</i> . . . . .	.Leptospirosis
<i>Yersinia</i> . . . . .	.Yersiniosis
<i>Escherichia coli</i> . . . . .	.Diarrhea
<b>Worms</b>	<b>Disease</b>
<i>Schistosoma haematobium</i> . . . . .	.schistosomiasis

Source: Feachem et al., 1980; and Franceys, et al. 1992; and Lewis, Ricki. (1992). *FDA Consumer*, September 1992. p. 41.

Table 7.2  
**MINIMAL INFECTIVE DOSES**  
**For Some Pathogens and Parasites**

<b>Pathogen</b>	<b>Minimal Infective Dose</b>
<i>Ascaris</i> . . . . .	1-10 eggs
<i>Cryptosporidium</i> . . . . .	10 cysts
<i>Entamoeba coli</i> . . . . .	10 cysts
<i>Escherichia coli</i> . . . . .	1,000,000-100,000,000
<i>Giardia lamblia</i> . . . . .	10-100 cysts
Hepatitis A virus . . . . .	1-10 PFU
<i>Salmonella</i> spp. . . . .	10,000-10,000,000
<i>Shigella</i> spp. . . . .	10-100
<i>Streptococcus fecalis</i> . . . . .	10,000,000,000
<i>Vibrio cholerae</i> . . . . .	1,000

Pathogens have various degrees of *virulence*, which is their potential for causing disease in humans. The minimal infective dose is the number of organisms needed to establish infection.

Source: Bitton, Gabriel. (1994). *Wastewater Microbiology*. New York: Wiley-Liss, Inc., p. 77-78. and *Biocycle*, September 1998, p. 62.

ary habits. It should be understood that the breath one exhales can also be the carrier of dangerous pathogens, as can one's saliva and sputum. The issue is confused by the notion that if something is potentially dangerous, then it is always dangerous, which is not true. Furthermore, it is generally not understood that the carefully managed thermophilic composting of humanure converts it into a sanitized agricultural resource. No other system of fecal material and urine recycling or disposal can achieve this without the use of dangerous chemical poisons or a high level of technology and energy consumption.

Even urine, usually considered sterile, can contain disease germs (see Table 7.1). Urine, like humanure, is valuable for its soil nutrients. It is estimated that one person's annual urine output contains enough soil nutrients to grow grain to feed that person for a year.<sup>13</sup> Therefore, it is just as important to recycle urine as it is to recycle humanure, and composting provides an excellent means for doing so.

The pathogens that can exist in humanure can be divided into four general categories: *viruses*, *bacteria*, *protozoa* and *worms (helminths)*.

## VIRUSES

First discovered in the 1890s by a Russian scientist, viruses are among the simplest and smallest of life forms. Many scientists don't even consider them to be organisms. They are much smaller and simpler than bacteria (some viruses are even parasitic to bacteria), and the simplest form may consist only of an RNA molecule. By definition, a virus is an entity which contains the information necessary for its own replication, but does not possess the physical elements for such replication — they have the software, but not the hardware. In order to reproduce, therefore, viruses rely on the hardware of the infected host cell which is re-programmed by the virus in order to reproduce viral nucleic acid. As such, viruses cannot reproduce outside the host cell.<sup>14</sup>

There are more than 140 types of viruses worldwide that can be passed through human feces, including polioviruses, coxsackieviruses (causing meningitis and myocarditis), echoviruses (causing meningitis and enteritis), reovirus (causing enteritis), adenovirus (causing respiratory illness), infectious hepatitis (causing jaundice), and others (see Table 7.3). During periods of infection, one hundred

Table 7.3

**POTENTIAL VIRAL PATHOGENS IN FECES**

<u>Virus</u>	<u>Disease</u>	<u>Can Carrier Be Symptomless?</u>
Adenoviruses .....	varies .....	yes
Coxsackievirus .....	varies .....	yes
Echoviruses .....	varies .....	yes
Hepatitis A.....	Infectious hepatitis .....	yes
Polioviruses .....	Poliomyelitis .....	yes
Reoviruses .....	varies .....	yes
Rotaviruses .....	Diarrhea .....	yes

Rotaviruses may be responsible for the majority of infant diarrheas. Hepatitis A causes infectious hepatitis, often without symptoms, especially in children. Coxsackievirus infection can lead to meningitis, fevers, respiratory diseases, paralysis, and myocarditis. Echovirus infection can cause simple fever, meningitis, diarrhea, or respiratory illness. Most poliovirus infections don't give rise to any clinical illness, although sometimes infection causes a mild, influenza-like illness which may lead to virus-meningitis, paralytic poliomyelitis, permanent disability, or death. It's estimated that almost everyone in developing countries becomes infected with poliovirus, and that one out of every thousand poliovirus infections leads to paralytic poliomyelitis.

Source: Feachem et al., 1980

Table 7.4

**POTENTIAL BACTERIAL PATHOGENS IN FECES**

<u>Bacteria</u>	<u>Disease</u>	<u>Symptomless Carrier?</u>
<i>Campylobacter</i> .....	Diarrhea .....	yes
<i>E. coli</i> .....	Diarrhea .....	yes
<i>Salmonella typhi</i> .....	Typhoid fever .....	yes
<i>Salmonella paratyphi</i> .....	Paratyphoid fever.....	yes
Other <i>Salmonellae</i> .....	Food poisoning .....	yes
<i>Shigella</i> .....	Dysentery.....	yes
<i>Vibrio cholerae</i> .....	Cholera .....	yes
Other <i>Vibrios</i> .....	Diarrhea .....	yes
<i>Yersinia</i> .....	Yersiniosis .....	yes

Source: Feachem et al., 1980

million to one trillion viruses can be excreted with each gram of fecal material.<sup>15</sup>

#### BACTERIA

Of the pathogenic bacteria, the genus *Salmonella* is significant because it contains species causing typhoid fever, paratyphoid, and gastrointestinal disturbances. Another genus of bacteria, *Shigella*, causes dysentery. Myobacteria cause tuberculosis (see Table 7.4). However, according to Gotaas, pathogenic bacteria “are unable to survive temperatures of 55°-60°C for longer than 30 minutes to one hour.”<sup>16</sup>

#### PROTOZOA

The pathogenic protozoa include *Entamoeba histolytica* (causing amoebic dysentery), and members of the Hartmanella-Naegleria group (causing meningo-encephalitis — see Table 7.5). The cyst stage in the life cycle of protozoa is the primary means of dissemination as the amoeba die quickly once outside the human body. Cysts must be kept moist in order to remain viable for any extended period.<sup>17</sup>

#### PARASITIC WORMS

Finally, a number of parasitic worms pass their eggs in feces, including hookworms, roundworms (*Ascaris*) and whipworms (see Table 7.6). Various researchers have reported 59 to 80 worm eggs in sampled liters of sewage. This suggests that billions of pathogenic worm eggs may reach an average wastewater treatment plant daily. These eggs tend to be resistant to environmental conditions due to a thick outer covering,<sup>18</sup> and they are extremely resistant to the sludge

Table 7.5  
**POTENTIAL PROTOZOAN PATHOGENS IN FECES**

<u>Protozoa</u>	<u>Disease</u>	<u>Symptomless Carrier?</u>
<i>Balantidium coli</i> .....	Diarrhea .....	yes
<i>Entamoeba histolytica</i> .....	Dysentery, colonic .....	yes
	ulceration, liver abscess	
<i>Giardia lamblia</i> .....	Diarrhea.....	yes

Source: Feachem et al., 1980

Table 7.6

**POTENTIAL WORM PATHOGENS IN FECES**

Note: hum. = human; intes.=intestinal; Chin.=Chinese; Vietn=Vietnam

<u>Common Name</u>	<u>Pathogen</u>	<u>Transmission</u>	<u>Distribution</u>
1. Hookworm . . . . .	<i>Ancylostoma duodenale</i> . . . . .	Hum.-soil-human. . . . .	Warm, wet climates
	<i>Necator americanus</i>		
2. ----- . . . . .	<i>Heterophyes heterophyes</i> . . . . .	Dog/cat-snail-fish-hum. . . . .	Mid. East/S. Eur./Asia
3. ----- . . . . .	<i>Gastroducooides</i> . . . . .	Pig -snail- . . . . .	India/Bangla./Vietn./Philippines
aquatic vegetation-hum.			
4. Giant intes. fluke . . . . .	<i>Fasciolopsis buski</i> . . . . .	Human/pig-snail- . . . . .	S.E. Asia/China
		aquatic vegetation-human	
5. Sheep liver fluke . . . . .	<i>Fasciola hepatica</i> . . . . .	Sheep -snail - . . . . .	Worldwide
		aquatic vegetation-human	
6. Pinworm . . . . .	<i>Enterobius vermicularis</i> . . . . .	Human-human . . . . .	Worldwide
7. Fish tapeworm . . . . .	<i>Diphyllobothrium latum</i> . . . . .	Human/animal-copepod - . . . . .	Mainly temperate fish-human
8. Cat liver fluke . . . . .	<i>Opisthorchis felineus</i> . . . . .	Animal-aquatic snail- . . . . .	USSR/Thailand
	<i>O. viverrini</i>	fish-human	
9. Chin. liver fluke . . . . .	<i>Clonorchis sinensis</i> . . . . .	Animal/human-snail-fish- . . . . .	S.E. Asia
		human	
10. Roundworm . . . . .	<i>Ascaris lumbricoides</i> . . . . .	Human-soil-human . . . . .	Worldwide
11. Dwarf tapeworm . . . . .	<i>Hymenolepis</i> spp. . . . . .	Human/rodent-human . . . . .	Worldwide
12. ----- . . . . .	<i>Metagonimus yokogawai</i> . . . . .	Dog/cat-snail-fish-hum. . . . .	Jap./Kor./Chi./Taiw./Siberia
13. Lung fluke . . . . .	<i>Paragonimus westermani</i> . . . . .	Animal/human-snail- . . . . .	S.E. Asia/Africa/
		crab/crayfish-human . . . . .	S. America
14. Schistosome, bil. . . . .	<i>S. haematobium</i> . . . . .	Human-snail-human . . . . .	Africa, M. East, India
----- . . . . .	<i>Schistosoma mansoni</i> . . . . .	Human-snail-human . . . . .	Afr., Arabia, Ltn. Amer.
----- . . . . .	<i>S. japonicum</i> . . . . .	Animal/hum.-snail-hum. . . . .	S.E. Asia
15. Threadworm . . . . .	<i>Strongyloides stercoralis</i> . . . . .	Hum.-hum. (dog-hum.?) . . . . .	Warm, wet climates
16. Beef tapeworm . . . . .	<i>Taenia saginata</i> . . . . .	Human-cow-human . . . . .	Worldwide
Pork tapeworm . . . . .	<i>T. solium</i> . . . . .	Human-pig-human or . . . . .	Worldwide
		human-human	
17. Whipworm . . . . .	<i>Trichuris trichiura</i> . . . . .	Human-soil-human . . . . .	Worldwide

Source: Feachem et al., 1980

digestion process common in wastewater treatment plants. Three months exposure to anaerobic sludge digestion processes appears to have little effect on the viability of *Ascaris* eggs; after six months, 10% of the eggs may still be viable. Even after a year in sludge, some viable eggs may be found.<sup>19</sup> In 1949, an epidemic of roundworm infestation in Germany was directly traced to the use of raw sewage to fertilize gardens. The sewage contained 540 *Ascaris* eggs per 100 ml, and over 90% of the population became infected.<sup>20</sup>

If there are about 59 to 80 worm eggs in a liter sample of sewage, then we could reasonably estimate that there are 70 eggs per liter, or 280 eggs per gallon to get a rough average. That means approximately 280 pathogenic worm eggs per gallon of wastewater could enter wastewater treatment plants. My local wastewater treatment plant serves a population of eight thousand people and collects about 1.5 million gallons of wastewater daily. That means there could be 420 million worm eggs entering the plant each day and settling into the sludge. In a year's time, over 153 *billion* parasitic eggs can pass through my local small-town wastewater facility. Let's look at the worst-case scenario: all the eggs survive in the sludge because they're resistant to the environmental conditions at the plant. During the year, 30 tractor-trailer loads of sludge are hauled out of the local facility. Each truckload of sludge could theoretically contain over 5 *billion* pathogenic worm eggs, en route to maybe a farmer's field, but probably to a landfill.

It is interesting to note that roundworms co-evolved over millennia as parasites of the human species by taking advantage of the long-standing human habit of defecating on soil. Since roundworms live in the human intestines, but require a period in the soil for their development, their species is perpetuated by our bad habits. If we humans never allowed our excrement to come in contact with soil, and if we instead composted it, the parasitic species known as *Ascaris lumbricoides*, a parasite that has plagued us for perhaps hundreds of thousands of years, would soon become extinct. The human species is finally evolving to the extent that we are beginning to understand compost and its ability to destroy parasites. We need to take that a step further and entirely prevent our excrement from polluting the environment. Otherwise, we will continue to be outsmarted by the parasitic worms that rely on our ignorance and carelessness for their own survival.

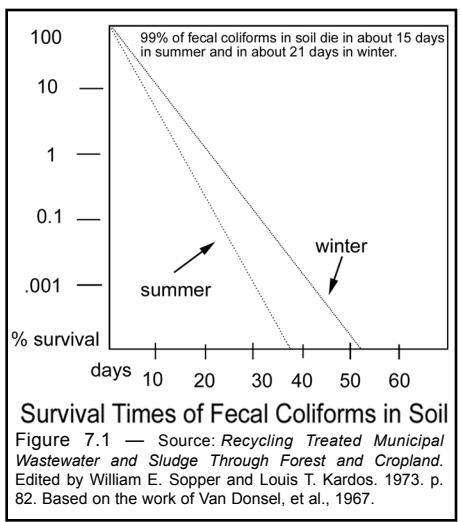


Table 7.7 AVERAGE DENSITY OF FECAL COLIFORMS EXCRETED IN 24 HOURS (million/100ml)	
Human.....	13.0
Duck.....	33.0
Sheep.....	16.0
Pig.....	3.3
Chicken.....	1.3
Cow.....	0.23
Turkey.....	0.29

## INDICATOR PATHOGENS

*Indicator pathogens* are pathogens whose detection in soil or water serves as evidence that fecal contamination exists. The astute reader will have noticed that many of the pathogenic worms listed in Table 7.6 are not found in the United States. Of those that are, the *Ascaris lumbricoides* (roundworm) is the most persistent, and can serve as an indicator for the presence of pathogenic helminths in the environment. A single female roundworm may lay as many as 27 million eggs in her lifetime.<sup>21</sup> These eggs are protected by an outer covering that is resistant to chemicals and enables the eggs to remain viable in soil for long periods of time. The egg shell is made of five separate layers: an outer and inner membrane, with three tough layers in between. The outer membrane may become partially hardened by hostile environmental influences.<sup>22</sup> The reported viability of roundworm eggs (*Ascaris ova*) in soil ranges from a couple of weeks under sunny, sandy conditions,<sup>23</sup> to two and a half years,<sup>24</sup> four years,<sup>25</sup> five and a half years,<sup>26</sup> or even ten years<sup>27</sup> in soil, depending on the source of the information. Consequently, the eggs of the roundworm seem to be the best indicator for determining if parasitic worm pathogens are present in compost. In China, current standards for the agricultural reuse of humanure require an *Ascaris* mortality of greater than 95%.

*Ascaris* eggs develop at temperatures between 15.5°C (59.90°F) and 35°C (95°F), but the eggs disintegrate at temperatures above 38°C (100.40°F).<sup>28</sup> The temperatures generated during thermophilic composting can easily exceed levels necessary to destroy roundworm eggs.

One way to determine if the compost you're using is contaminated with viable roundworm eggs is to have a stool analysis done at a local hospital. If your compost is contaminated and you're using the compost to grow your own food, then there will be a chance that you've contaminated yourself. A stool analysis will reveal whether that is the case or not. Such an analysis is relatively inexpensive.

I subjected myself to three stool examinations over a period of twelve years as part of the research for this book. I had been composting humanure for fourteen years at the time of the first testing, and 26 years at the time of the third. I had used all of the compost in my food gardens. Hundreds of other people had also used my toilet over the years, potentially contaminating it with *Ascaris*. Yet, all stool examinations were completely negative. As of this writing, nearly three decades have passed since I began gardening with humanure compost. During those years, I have raised several healthy children. Our toilet has been used by countless people, including many strangers. All of the toilet material has been composted and used for gardening purposes in our home garden.

There are indicators other than roundworm eggs that can be used to determine contamination of water, soil or compost. *Indicator bacteria* include fecal coliforms, which reproduce in the intestinal systems of warm blooded animals (see Table 7.7). If one wants to test a water supply for fecal contamination, then one looks for fecal coliforms, usually *Escherichia coli*. *E. coli* is one of the most abundant intestinal bacteria in humans; over 200 specific types exist. Although some of them can cause disease, most are harmless.<sup>29</sup> The absence of *E. coli* in water indicates that the water is free from fecal contamination.

Water tests often determine the level of *total coliforms* in the water, reported as the number of coliforms per 100 ml. Such a test measures *all* species of the coliform group and is not limited to species originating in warm-blooded animals. Since some coliform species come from the soil, the results of this test are not always indicative of fecal contamination in a stream analysis. However, this test can be used for ground water supplies, as no coliforms should be present in ground water unless it has been contaminated by a warm-blooded animal.

*Fecal coliforms* do not multiply outside the intestines of warm-blooded animals, and their presence in water is unlikely unless there is fecal pollution. They survive for a shorter time in natural waters than the coliform group as a whole, therefore their presence

indicates relatively recent pollution. In domestic sewage, the fecal coliform count is usually 90% or more of the total coliform count, but in natural streams, fecal coliforms may contribute 10-30% of the total coliform density. Almost all natural waters have a presence of fecal coliforms, since all warm-blooded animals excrete them. Most states in the U.S. limit the fecal coliform concentration allowable in waters used for water sports to 200 fecal coliforms per 100 ml.

Bacterial analyses of drinking water supplies are routinely provided for a small fee by agricultural supply firms, water treatment companies or private labs.

### PERSISTENCE OF PATHOGENS IN SOIL, CROPS, MANURE, AND SLUDGE

According to Feachem et al. (1980), the persistence of fecal pathogens in the environment can be summarized as follows:

#### IN SOIL

Survival times of pathogens in soil are affected by soil moisture, pH, type of soil, temperature, sunlight and organic matter. Although fecal coliforms can survive for several years under optimum conditions, a 99% reduction is likely within 25 days in warm climates (see Figure 7.1). *Salmonella* bacteria may survive for a year in rich, moist, organic soil, although 50 days would be a more typical survival time. Viruses can survive up to three months in warm weather, and up to six months in cold. Protozoan cysts are unlikely to survive for more than ten days. Roundworm eggs can survive for several years.

The viruses, bacteria, protozoa and worms that can be excreted in humanure all have limited survival times outside of the human body. Tables 7.8 through 7.12 reveal their survival times in soil.

#### SURVIVAL OF PATHOGENS ON CROPS

Bacteria and viruses are unlikely to penetrate undamaged vegetable skins. Furthermore, pathogens are unlikely to be taken up in the roots of plants and transported to other portions of the plant,<sup>30</sup> although research published in 2002 indicates that at least one type of *E. coli* can enter lettuce plants through the root systems and travel throughout the edible portions of the plant.<sup>AA</sup>

Some pathogens can survive on the surfaces of vegetables,

especially root vegetables, although sunshine and low air humidity will promote the death of pathogens. Viruses can survive up to two months on crops but usually live less than one month. Indicator bacteria may persist several months, but usually less than one month. Protozoan cysts usually survive less than two days, and worm eggs usually last less than one month. In studies of the survival of *Ascaris* eggs on lettuce and tomatoes during a hot, dry summer, all eggs degenerated enough after 27 to 35 days to be incapable of infection.<sup>31</sup>

Lettuce and radishes in Ohio sprayed with sewage inoculated with Poliovirus I showed a 99% reduction in pathogens after six days; 100% were eliminated after 36 days. Radishes grown outdoors in soil fertilized with fresh typhoid-contaminated feces four days after planting showed a pathogen survival period of less than 24 days. Tomatoes and lettuce contaminated with a suspension of roundworm eggs showed a 99% reduction in eggs in 19 days and a 100% reduction in four weeks. These tests indicate that if there is any doubt about pathogen contamination of compost, the compost should be applied to long-season crops at the time of planting so that sufficient time ensues for the pathogens to die before harvest.

#### PATHOGEN SURVIVAL IN SLUDGE AND FECES/URINE

Viruses can survive up to five months, but usually less than three months in sludge and night soil. Indicator bacteria can survive up to five months, but usually less than four months. *Salmonellae* survive up to five months, but usually less than one month. Tubercl bacilli survive up to two years, but usually less than five months. Protozoan cysts survive up to one month, but usually less than ten days. Worm eggs vary depending on species, but roundworm eggs may survive for many months.

#### PATHOGEN TRANSMISSION THROUGH VARIOUS TOILET SYSTEMS

It is clearly evident that human excrement possesses the capability to transmit various diseases. For this reason, it should also be evident that the composting of humanure is a serious undertaking and should not be done in a frivolous, careless or haphazard manner. The pathogens that may be present in humanure have various survival periods outside the human body and maintain varied capacities for re-infecting people. This is why the *careful management* of a ther-

Table 7.8  
**SURVIVAL OF ENTEROVIRUSES IN SOIL**

**Viruses** - These parasites, which are smaller than bacteria, can only reproduce inside the animal or plant they parasitize. However, some can survive for long periods outside of their host.

**Enteroviruses** - Enteroviruses are those that reproduce in the intestinal tract. They have been found to survive in soil for periods ranging between 15 and 170 days. The following chart shows the survival times of enteroviruses in various types of soil and soil conditions.

<u>Soil Type</u>	<u>pH</u>	<u>% Moisture</u>	<u>Temp. (°C)</u>	<u>Days of Survival</u> (less than)
Sterile, sandy	7.5	10-20%	3-10	130-170
		10-20%	18-23	90-110
	5.0	10-20%	3-10	110-150
		10-20%	18-23	40-90
Non-sterile, sandy	7.5	10-20%	3-10	110-170
		10-20%	18-23	40-110
	5.0	0-20%	3-10	90-150
		10-20%	18-23	25-60
Sterile, loamy	7.5	10-20%	3-10	70-150
		10-20%	18-23	70-110
	5.0	10-20%	3-10	90-150
		10-20%	18-23	25-60
Non-sterile, loamy	7.5	10-20%	3-10	110-150
		10-20%	18-23	70-110
	5.0	10-20%	10	90-130
		10-20%	18-23	25-60
Non-sterile, sandy	7.5	10-20%	18-23	15-25

Source: Feachem et al., 1980

Table 7.9  
**SURVIVAL TIME OF *E. HISTOLYTICA* PROTOZOA IN SOIL**

<u>Protozoa</u>	<u>Soil</u>	<u>Moisture</u>	<u>Temp (°C)</u>	<u>Survival</u>
<i>E. histolytica</i>	loam/sand	Damp	28-34	8-10 days
<i>E. histolytica</i>	soil	Moist	?	42-72 hrs.
<i>E. histolytica</i>	soil	Dry	?	18-42 hrs.

Source: Feachem et al., 1980

Table 7.10

**SURVIVAL TIMES OF SOME BACTERIA IN SOIL**

<u>Bacteria</u>	<u>Soil</u>	<u>Moisture</u>	<u>Temp.(°C)</u>	<u>Survival</u>
<i>Streptococci</i> . . . . .	Loam . . . . .	? . . . . .	? . . . . .	9-11 weeks
<i>Streptococci</i> . . . . .	Sandy loam .	? . . . . .	? . . . . .	5-6 weeks
<i>S. typhi</i> . . . . .	various soils .	? . . . . .	22 . . . . .	2 days-400 days
Bovine tubercle bacilli	soil & dung .	? . . . . .	? . . . . .	less than 178 days
Leptospires	.varied . . . . .	.varied . . . . .	summer . . . . .	12 hrs-15 days

Source: Feachem et al., 1980

Table 7.11

**SURVIVAL OF POLIOVIRUSES IN SOIL**

<u>Soil Type</u>	<u>Virus</u>	<u>Moisture</u>	<u>Temp. (C)</u>	<u>Days Survival</u>
Sand dunes . . . . .	Poliovirus . . . . .	dry . . . . .	? . . . . .	Less than 77
Sand dunes . . . . .	Poliovirus . . . . .	moist . . . . .	? . . . . .	Less than 91
Loamy fine sand . . . . .	Poliovirus I . . . . .	moist . . . . .	4 . . . . .	90% red. in 84
Loamy fine sand	Poliovirus I	moist	20	99.999% reduction in 84
Soil irrigated w/ effluent, pH=8.5	Polioviruses . . . . .	9-20% . . . . .	12-33 . . . . .	Less than 8
Sludge or effluent . . . . .	Poliovirus I . . . . .	180 mm . . . . .	-14-27 . . . . .	96-123 after sludge applied
		total rain	-14-27	89-96 after effluent applied
		190 mm . . . . .	15-33 . . . . .	less than 11 after sludge or effluent applied
		total rain		

Source: Feachem et al., 1980

Table 7.12

**SURVIVAL TIME OF SOME PATHOGENIC WORMS IN SOIL**

<u>Soil</u>	<u>Moisture</u>	<u>Temp. (°C)</u>	<u>Survival</u>
<b>HOOKWORM LARVAE</b>			
Sand	? .....	room temp.	< 4 months
Soil	? .....	open shade,	< 6 months
Soil	Moist .....	Dense shade ..	9-11 weeks
		Mod. shade ..	6-7.5 weeks
		Sunlight .....	5-10 days
Soil	Water covered .....	varied .....	10-43 days
Soil	Moist .....	0 .....	< 1 week
		16 .....	14-17.5 weeks
		27 .....	9-11 weeks
		35 .....	< 3 weeks
		40 .....	< 1 week
<b>HOOKWORM OVA (EGGS)</b>			
Heated soil with night soil	water covered .....	15-27 .....	.9% after 2wks
Unheated soil with night soil	water covered .....	15-27 .....	.3% after 2wks
<b>ROUNDWORM OVA</b>			
Sandy, shaded	.....	25-36 .....	.31% dead after 54 d.
Sandy, sun	.....	24-38 .....	.99% dead after 15 d.
Loam, shade	.....	25-36 .....	.3.5% dead after 21 d.
Loam, sun	.....	24-38 .....	.4% dead after 21 d.
Clay, shade	.....	25-36 .....	.2% dead after 21 d.
Clay, sun	.....	24-38 .....	.12% dead after 21 d.
Humus, shade	.....	25-36 .....	.1.5% dead after 22 d.
Clay, shade	.....	22-35 .....	more than 90 d.
Sandy, shade	.....	22-35 .....	less than 90 d.
Sandy, sun	.....	22-35 .....	less than 90 d.
Soil irrigated w/sewage	.....	? .....	less than 2.5 yrs.
Soil	.....	? .....	.2 years

Source: Feachem et al., 1980; d.=days; &lt;=less than

Table 7.13

**PARASITIC WORM EGG DEATH**

<u>Eggs</u>	<u>Temp.(°C)</u>	<u>Survival</u>
Schistosome .....	53.5 .....	1 minute
Hookworm .....	55.0 .....	1 minute
Roundworm .....	-30.0 .....	24 hours
Roundworm .....	0.0 .....	4 years
Roundworm .....	55.0 .....	10 minutes
Roundworm .....	60.0 .....	.5 seconds

Source: *Compost, Fertilizer, and Biogas Production from Human and Farm Wastes in the People's Republic of China*, (1978), M. G. McGarry and J. Stainforth, editors, International Development Research Center, Ottawa, Canada. p. 43.

mophilic compost system is important. Nevertheless, there is no proven, natural, low-tech method for destroying human pathogens in organic refuse that is as successful *and* accessible to the average human as well-managed thermophilic composting.

But what happens when the compost is not well-managed? How dangerous is the undertaking when those involved do not make an effort to ensure that the compost maintains thermophilic temperatures? In fact, this is normally what happens in most owner-built and commercial composting toilets. Thermophilic composting does not occur in owner-built toilets because those responsible often make no effort to create the organic blend of ingredients and the environment needed for such a microbial response. In the case of most commercial composting toilets, thermophilic composting is not even intended, as the toilets are designed to be dehydrators rather than thermophilic composters.

On several occasions, I have seen simple collection toilet systems (sawdust toilets) in which the compost was simply dumped in an outdoor pile, not in a bin, lacking urine (and thereby moisture), and not layered with the coarse organic material needed for air entrapment. Although these piles of compost did not give off unpleasant odors (most people have enough sense to instinctively cover odorous organic material in a compost pile), they also did not necessarily become thermophilic (their temperatures were never checked). People who are not very concerned about working with and managing their compost are usually willing to let the compost sit for years before use, if they use it at all. Persons who are casual about their composting tend to be those who are comfortable with their own state of health and therefore do not fear their own excrement. As long as they are combining their humanure with a carbonaceous material and letting it compost, thermophilically or not, for at least a year (an additional year of aging is recommended), they are very unlikely to be creating any health problems. What happens to these casually constructed compost piles? Incredibly, after a couple of years, they turn into humus and, if left entirely alone, will simply become covered with vegetation and disappear back into the earth. I have seen it with my own eyes.

A different situation occurs when humanure from a highly pathogenic population is being composted. Such a population would be the residents of a hospital in an underdeveloped country, for example, or any residents in a community where certain diseases or parasites are endemic. In that situation, the composter must make every

effort necessary to ensure thermophilic composting, adequate aging time and adequate pathogen destruction.

The following information illustrates the various waste treatment methods and composting methods commonly used today and shows the transmission of pathogens through the individual systems.

#### OUTHOUSES AND PIT LATRINES

Outhouses have odor problems, breed flies and possibly mosquitoes, and pollute groundwater. However, if the contents of a pit latrine have been filled over and left for a minimum of one year, there will be no surviving pathogens except for the possibility of round-worm eggs, according to Feachem. This risk is small enough that the contents of pit latrines, after twelve months burial, can be used agriculturally. Franceys et al. state, “*Solids from pit latrines are innocuous if the latrines have not been used for two years or so, as in alternating double pits.*”<sup>32</sup>

#### SEPTIC TANKS

It is safe to assume that septic tank effluents and sludge are highly pathogenic (see Figure 7.3). Viruses, parasitic worm eggs, bacteria and protozoa can be emitted from septic tank systems in viable condition.

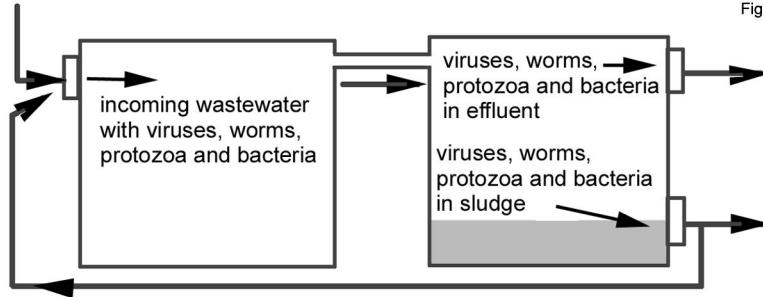
#### CONVENTIONAL SEWAGE TREATMENT PLANTS

The only sewage digestion process producing a guaranteed pathogen-free sludge is batch thermophilic digestion in which all of the sludge is maintained at 50°C (122°F) for 13 days. Other sewage digestion processes will allow the survival of worm eggs and possibly pathogenic bacteria. Typical sewage treatment plants instead use a continuous process where wastewater is added daily or more frequently, thereby guaranteeing the survival of pathogens (see Figure 7.2).

I took an interest in my local wastewater treatment plant when I discovered that the water in our local creek below the wastewater discharge point had ten times the level of nitrates that unpolluted water has, and three times the level of nitrates acceptable for drinking water.<sup>33</sup> In other words, the water being discharged from the water treatment plant was polluted. We had tested the water for

## Transmission of Pathogens Through Wastewater Plants

Figure 7.2



Conventional wastewater treatment plants allow the transmission of pathogens. Consequently, the effluent is commonly treated with chemicals such as chlorine and the sludge is often buried in landfills.

## Transmission of Pathogens Through Septic Tanks

Figure 7.3

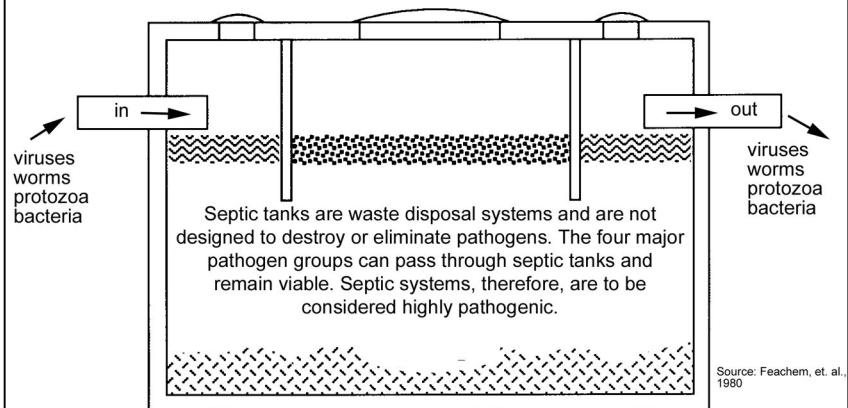
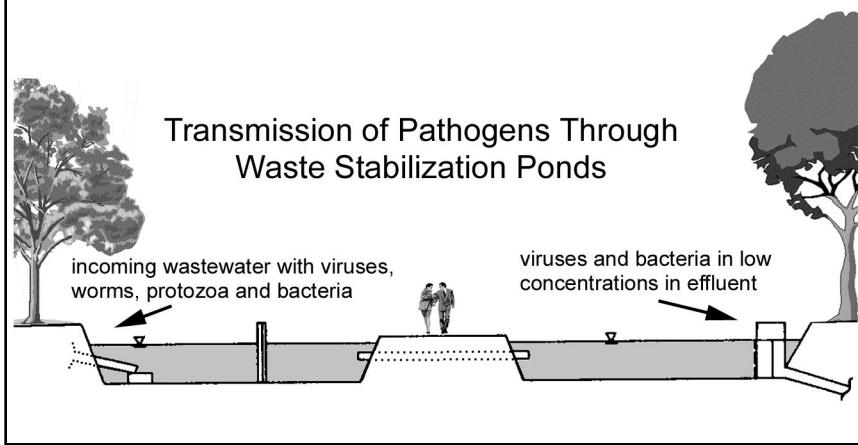


Figure 7.4

## Transmission of Pathogens Through Waste Stabilization Ponds



nitrates, but we didn't test for pathogens or chlorine levels. Despite the pollution, the nitrate levels were *within legal limits* for wastewater discharges.

#### WASTE STABILIZATION PONDS

Waste stabilization ponds, or lagoons, large shallow ponds widely used in North America, Latin America, Africa and Asia, involve the use of both beneficial bacteria and algae in the decomposition of organic waste materials. Although they can breed mosquitoes, they can be designed and managed well enough to yield pathogen-free waste water. However, they typically yield water with low concentrations of both pathogenic viruses and bacteria (see Figure 7.4).

#### COMPOSTING TOILETS AND MOULDERING TOILETS

Most mouldering and commercial composting toilets are relatively anaerobic and compost at a low temperature. According to Feachem et al., a minimum retention time of three months produces a compost free of all pathogens except possibly some intestinal worm eggs. The compost obtained from these types of toilets can theoretically be composted again in a thermophilic pile and rendered suitable for food gardens (see Figure 7.5 and Table 7.14). Otherwise, the compost can be moved to an outdoor compost bin, layered and covered with straw (or other bulky organic material such as weeds or leaf mould), moistened, and left to age for an additional year or two in order to destroy any possible lingering pathogens. Microbial activity and earthworms will aid in the sanitation of the compost over time.

#### WELL-MANAGED THERMOPHILIC COMPOSTING SYSTEM

Complete pathogen destruction is guaranteed by arriving at a temperature of 62°C (143.6°F) for one hour, 50°C (122°F) for one day, 46°C (114.8°F) for one week or 43°C (109.4°F) for one month. It appears that no excreted pathogen can survive a temperature of 65°C (149°F) for more than a few minutes. A compost pile containing entrapped oxygen may rapidly rise to a temperature of 55°C (131°F) or above, or will maintain a temperature hot enough for a long enough period of time to destroy human pathogens beyond a detectable level (see Figure 7.6). As pathogen destruction is aided by

microbial diversity, as discussed in Chapter 3, excessively heating a compost pile, such as by forcing air through it, can be counter-productive.

Table 7.14 indicates survival times of pathogens in a) soil, b) anaerobic decomposition conditions, c) composting toilets and d) thermophilic compost piles.

## MORE ON PARASITIC WORMS

This is a good subject to discuss in greater detail as it is rarely a topic of conversation in social circles, yet it is important to those who are concerned about potential pathogens in compost. Therefore, let's look at the most common of human worm parasites: pinworms, hookworms, whipworms and roundworms.

### PINWORMS

A couple of my kids had pinworms at one time during their childhood. I know exactly who they got them from (another kid), and getting rid of them was a simple matter. However, the rumor was cir-

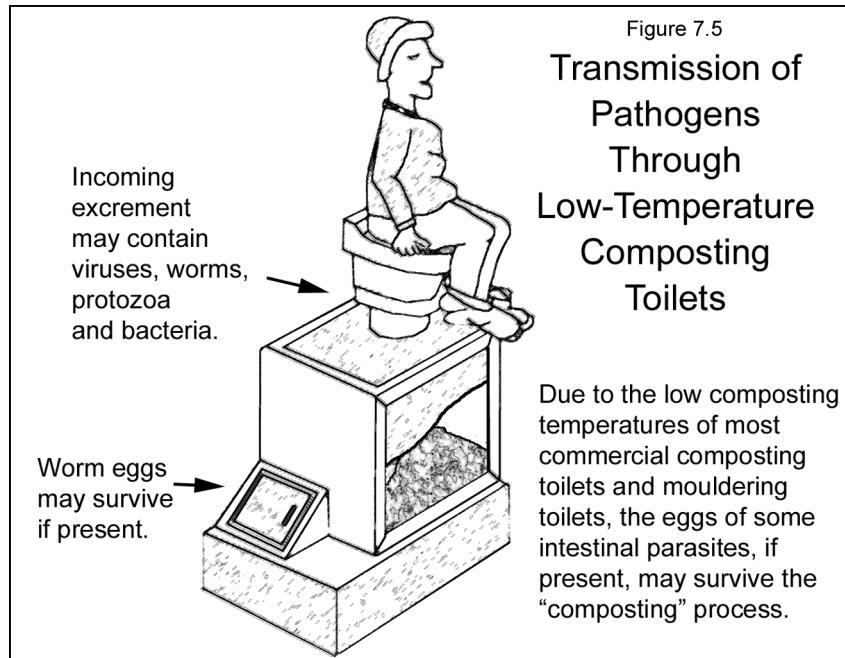
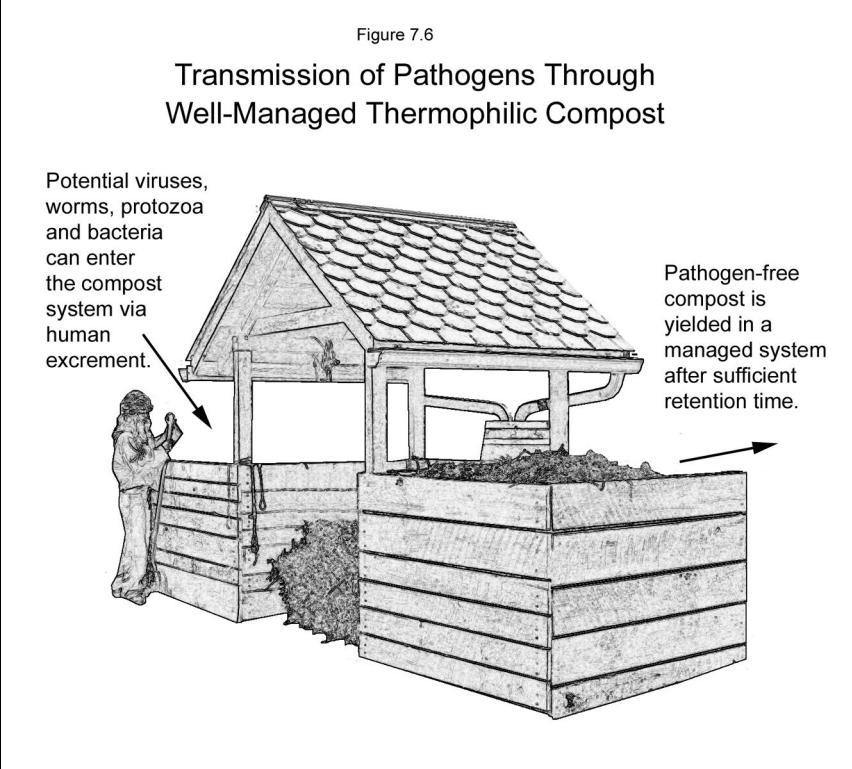


Figure 7.6

### Transmission of Pathogens Through Well-Managed Thermophilic Compost



culated that they got them from our compost. We were also told to worm our cats to prevent pinworms in the kids (these rumors allegedly originated in a doctor's office). Yet, the pinworm life cycle does not include a stage in soil, compost, manure or cats. These unpleasant parasites are spread from human to human by direct contact, and by inhaling eggs.

Pinworms (*Enterobius vermicularis*) lay microscopic eggs at the anus of a human being, its only known host. This causes itching at the anus which is the primary symptom of pinworm infestation. The eggs can be picked up almost anywhere. Once in the human digestive system they develop into the tiny worms. Some estimate that pinworms infest or have infested 75% of all New York City children in the three to five year age group, and that similar figures exist for other cities.<sup>34</sup>

These worms have the widest geographic distribution of any of the worm parasites, and are estimated to infect 208.8 million people in the world (18 million in Canada and the U.S.). An Eskimo village was found to have a 66% infection rate; a 60% rate has been found in Brazil, and a 12% to 41% rate in Washington D.C.

Table 7.14  
PATHOGEN SURVIVAL BY COMPOSTING OR SOIL APPLICATION

<u>Pathogen</u>	<u>Soil Application</u>	<u>Unheated Anaerobic Digestion</u>	<u>Composting Toilet retention time)</u>	<u>Thermophilic Composting</u>
Enteric viruses . . .	May survive 5 mo . . .	Over 3 mo. . . . .	Probably elim. . . . .	Killed rapidly at 60C
<i>Salmonellae</i> . . . . .	3 mo. to 1 yr. . . . .	Several wks. . . . .	Few may surv. . . . .	Dead in 20 hrs. at 60C
<i>Shigellae</i> . . . . .	Up to 3 mo. . . . .	A few days . . . . .	Prob. elim. . . . .	Killed in 1 hr. at 55C or in 10 days at 40C
<i>E. coli</i> . . . . .	Several mo. . . . .	Several wks. . . . .	Prob. elim. . . . .	Killed rapidly above 60C
<i>Cholera vibrio</i> . . . . .	1 wk. or less . . . . .	1 or 2 wks. . . . .	Prob. elim. . . . .	Killed rapidly above 55C
Leptospires . . . . .	Up to 15 days . . . . .	2 days or less . . . . .	Eliminated . . . . .	Killed in 10 min. at 55C
<i>Entamoeba histolytica</i> cysts . . . . .	1 wk. or less . . . . .	3 wks or less . . . . .	Eliminated . . . . .	Killed in 5 min. at 50C or 1 day at 40° C
Hookworm . . . . .	20 weeks . . . . .	Will survive . . . . .	May survive . . . . .	Killed in 5 min. at 50C or 1 hr. at 45C
Roundworm . . . . .	Several yrs. . . . .	Many mo. . . . .	Survive well . . . . .	Killed in 2 hrs. at 55C, 20 hrs. at 50C, 200 hrs. at 45°C
Schistosome . . . . .	One mo. . . . .	One mo. . . . .	Eliminated . . . . .	Killed in 1 hr. at 50°C eggs
Taenia eggs . . . . .	Over 1 year . . . . .	A few mo. . . . .	May survive . . . . .	Killed in 10 min. at 59°C, over 4 hrs. at 45°C

Source: Feachem et al., 1980

Table 7.15  
THERMAL DEATH POINTS FOR COMMON PARASITES AND PATHOGENS

<u>PATHOGEN</u>	<u>THERMAL DEATH</u>
<i>Ascaris lumbricoides</i> eggs . . . . .	Within 1 hour at temps over 50°C
<i>Brucella abortus</i> or <i>B. suis</i> . . . . .	Within 1 hour at 55°C
<i>Corynebacterium diphtheriae</i> . . . . .	Within 45 minutes at 55°C
<i>Entamoeba histolytica</i> cysts . . . . .	Within a few minutes at 45°C
<i>Escherichia coli</i> . . . . .	One hr at 55°C or 15-20 min. at 60°C
<i>Micrococcus pyogenes</i> var. <i>aureus</i> . . . . .	Within 10 minutes at 50°C
<i>Mycobacterium tuberculosis</i> var. <i>hominis</i> . . . . .	Within 15 to 20 minutes at 66°C
<i>Necator americanus</i> . . . . .	Within 50 minutes at 45°C
<i>Salmonella</i> spp. . . . .	Within 1 hr at 55C; 15-20 min. at 60°C
<i>Salmonella typhosa</i> . . . . .	No growth past 46C; death in 30 min. 55C
<i>Shigella</i> spp. . . . .	Within one hour at 55°C
<i>Streptococcus pyogenes</i> . . . . .	Within 10 minutes at 54°C
<i>Taenia saginata</i> . . . . .	Within a few minutes at 55°C
<i>Trichinella spiralis</i> larvae . . . . .	Quickly killed at 55°C

Source: Gotaas, Harold B. (1956). *Composting - Sanitary Disposal and Reclamation of Organic Wastes*. p.81. World Health Organization, Monograph Series Number 31. Geneva.

Infection is spread by the hand to mouth transmission of eggs resulting from scratching the anus, as well as from breathing airborne eggs. In households with several members infected with pinworms, 92% of dust samples contained the eggs. The dust samples were collected from tables, chairs, baseboards, floors, couches, dressers, shelves, window sills, picture frames, toilet seats, mattresses, bath tubs, wash basins and bed sheets. Pinworm eggs have also been found in the dust from school rooms and school cafeterias. Although dogs and cats do not harbor pinworms, the eggs can get on their fur and find their way back to their human hosts. In about one-third of infected children, eggs may be found under the fingernails.

Pregnant female pinworms contain 11,000 to 15,000 eggs. Fortunately, pinworm eggs don't survive long outside their host. Room temperature with 30% to 54% relative humidity will kill off more than 90% of the eggs within two days. At higher summer temperatures, 90% will die within three hours. Eggs survive longest (two to six days) under cool, humid conditions; in dry air, none will survive for more than 16 hours.

A worm's life span is 37-53 days; an infection would self-terminate in this period, without treatment, in the absence of reinfection. The amount of time that passes from ingestion of eggs to new eggs being laid at the anus ranges from four to six weeks.<sup>35</sup>

*In 95% of infected persons, pinworm eggs aren't found in the feces.* Transmission of eggs to feces and to soil is not part of the pinworm life cycle, which is one reason why the eggs aren't likely to end up in either feces or compost. Even if they do, they quickly die outside the human host.

One of the worst consequences of pinworm infestation in children is the trauma of the parents, whose feelings of guilt, no matter how clean and conscientious they may be, are understandable. However, if you're composting your manure, you can be sure that you are not thereby breeding or spreading pinworms. Quite the contrary, any pinworms or eggs getting into your compost are being destroyed.<sup>36</sup>

## HOOKWORMS

Hookworm species in humans include *Necator americanus*, *Ancylostoma duodenale*, *A. braziliense*, *A. caninum* and *A. ceylanicum*.

These small worms are about a centimeter long, and humans are almost the exclusive host of *A. duodenale* and *N. americanus*. A

hookworm of cats and dogs, *A. caninum*, is an extremely rare intestinal parasite of humans.

The eggs are passed in the feces and mature into larvae outside the human host in favorable conditions. The larvae attach themselves to the human host usually at the bottom of the foot when they're walked on, then enter their host through pores, hair follicles, or even unbroken skin. They tend to migrate to the upper small intestine where they suck their host's blood. Within five or six weeks, they'll mature enough to produce up to 20,000 eggs per day.

Hookworms are estimated to infect 500 million people throughout the world, causing a daily blood loss of more than 1 million liters, which is as much blood as can be found in all the people in the city of Erie, PA, or Austin, TX. An infection can last two to fourteen years. Light infections can produce no recognizable symptoms, while a moderate or heavy infection can produce an iron deficiency anemia. Infection can be determined by a stool analysis.

These worms tend to be found in tropical and semi-tropical areas and are spread by defecating on the soil. Both the high temperatures of composting and the freezing temperatures of winter will kill the eggs and larvae (see Table 7.16). Drying is also destructive.<sup>37</sup>

#### WHIPWORM

Whipworms (*Trichuris trichiura*) are usually found in humans, but may also be found in monkeys or hogs. They're usually under two inches long; the female can produce 3,000 to 10,000 eggs per day. Larval development occurs outside the host, and in a favorable envi-

Table 7.16  
HOOKWORMS

Hookworm larvae develop outside the host and favor a temperature range of 23°C to 33°C (73°F to 91°F).

<u>Temperature</u>	<u>Eggs</u>	<u>Larvae</u>
45°C (113°F) .....	.Few hours .....	.less than 1 hour
0°C (32°F) .....	.7 days .....	.less than 2 weeks
-11°C (12°F) .....	? .....	.less than 24 hours

Both thermophilic composting and freezing weather will kill hookworms and eggs.

ronment (warm, moist, shaded soil), first stage larvae are produced from eggs in three weeks. The lifespan of the worm is usually considered to be four to six years.

Hundreds of millions of people worldwide, as much as 80% of the population in certain tropical countries, are infected by whipworms. In the U.S., whipworms are found in the south where heavy rainfall, a subtropical climate, and feces-contaminated soil provide a suitable habitat.

Persons handling soil that has been defecated on by an infected person risk infection by hand-to-mouth transmission. Infection results from ingestion of the eggs. Light infections may not show any symptoms. Heavy infections can result in anemia and death. A stool examination will determine if there is an infection.

Cold winter temperatures of  $-8^{\circ}\text{C}$  to  $-12^{\circ}\text{C}$  ( $17.6^{\circ}\text{F}$  to  $10.4^{\circ}\text{F}$ ) are fatal to the eggs, as are the high temperatures of thermophilic composting.<sup>38</sup>

#### ROUNDWORMS

Roundworms (*Ascaris lumbricoides*) are fairly large worms (10 inches in length) which parasitize the human host by eating semi-digested food in the small intestine. The females can lay 200,000 eggs per day for a lifetime total of 26 million or so. Larvae develop from the eggs *in soil* under favorable conditions ( $21^{\circ}\text{C}$  to  $30^{\circ}\text{C}/69.8^{\circ}\text{F}$  to  $86^{\circ}\text{F}$ ). Above  $37^{\circ}\text{C}$  ( $98.6^{\circ}\text{F}$ ), they cannot fully develop.

Approximately 900 million people are infected with roundworms worldwide, one million in the United States. The eggs are usually transmitted hand to mouth by people, usually children, who have come into contact with the eggs in their environment. Infected persons usually complain of a vague abdominal pain. Diagnosis is by stool analysis.<sup>39</sup> An analysis of 400,000 stool samples throughout the U.S. by the Center for Disease Control found *Ascaris* in 2.3% of the samples, with a wide fluctuation in results depending on the geographical location of the person sampled. Puerto Rico had the highest positive sample frequency (9.3%), while samples from Wyoming, Arizona, and Nevada showed no incidence of *Ascaris* at all.<sup>40</sup> In moist tropical climates, roundworm infection may afflict 50% of the population.<sup>41</sup>

Eggs are destroyed by direct sunlight within 15 hours, and are killed by temperatures above  $40^{\circ}\text{C}$  ( $104^{\circ}\text{F}$ ), dying within an hour at  $50^{\circ}\text{C}$  ( $122^{\circ}\text{F}$ ). Roundworm eggs are resistant to freezing temperatures,

chemical disinfectants and other strong chemicals, but thermophilic composting will kill them.

Roundworms, like hookworms and whipworms, are spread by fecal contamination of soil. Much of this contamination is caused and spread by children who defecate outdoors within their living area. One sure way to eradicate fecal pathogens is to conscientiously collect and thermophilically compost *all* fecal material. Therefore, it is very important when composting humanure to be certain that *all* children use the toilet facility and do not defecate elsewhere. When changing soiled diapers, scrape the fecal material into a humanure toilet with toilet paper or another biodegradable material. It's up to adults to keep an eye on kids and make sure they understand the importance of *always using a toilet facility*.

Fecal environmental contamination can also be caused by using raw fecal material for agricultural purposes. *Proper thermophilic composting of all fecal material is essential for the eradication of fecal pathogens.*

And don't forget to wash your hands before eating!

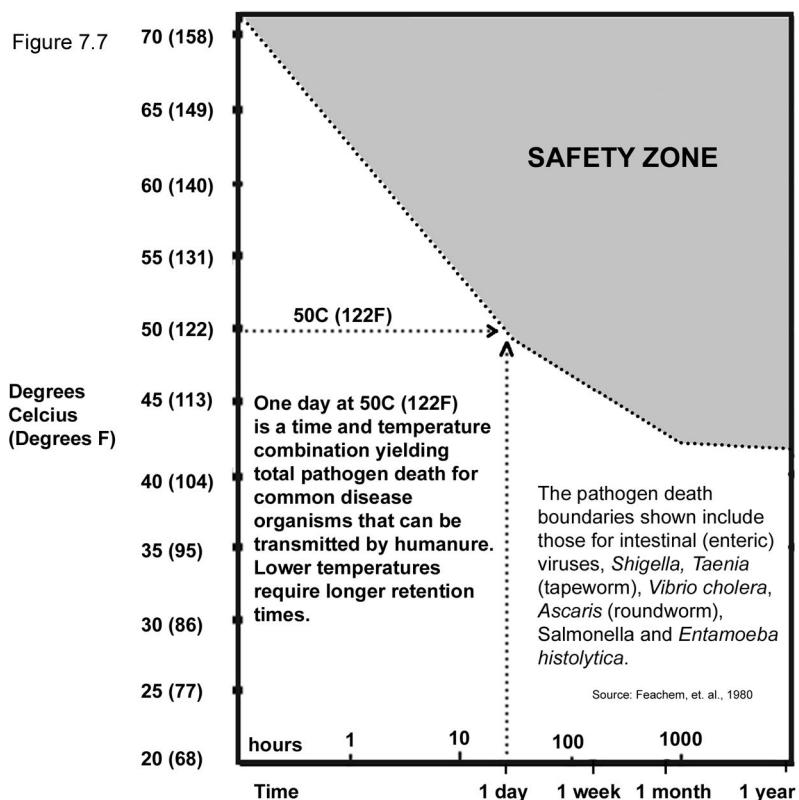
## TEMPERATURE AND TIME

There are two primary factors leading to the death of pathogens in humanure. The first is *temperature*. A compost pile that is properly managed will destroy pathogens with the heat and biological activity it generates.

The second factor is *time*. The lower the temperature of the compost, the longer the subsequent retention time needed for the destruction of pathogens. Given enough time, the wide biodiversity of microorganisms in the compost will destroy pathogens by the antagonism, competition, consumption and antibiotic inhibitors provided by the beneficial microorganisms. Feachem et al. state that three months retention time will kill all of the pathogens in a low-temperature composting toilet except worm eggs, although Table 7.14 (also from Feachem) indicates that some additional pathogen survival may occur.

A thermophilic compost pile will destroy pathogens, including worm eggs, quickly, possibly in a matter of minutes. Lower temperatures require longer periods of time, possibly hours, days, weeks, or months, to effectively destroy pathogens. One need not strive for extremely high temperatures such as 65°C (150°F) in a compost pile to feel confident about the destruction of pathogens. It may be more

Figure 7.7



realistic to maintain lower temperatures in a compost pile for longer periods of time, such as 50°C (122°F) for 24 hours, or 46°C (115°F) for a week. According to one source, “*All fecal microorganisms, including enteric viruses and roundworm eggs, will die if the temperature exceeds 46°C (114.8°F) for one week.*”<sup>42</sup> Other researchers have drawn similar conclusions, demonstrating pathogen destruction at 50°C (122°F), which produced compost “completely acceptable from the general hygienic point of view.”<sup>43</sup>

A sound approach to pathogen destruction when composting humanure is to thermophilically compost the toilet material, then allow the compost to sit, undisturbed, for a lengthy period of time after the thermophilic heating stage has ended. The biodiversity of the compost will aid in the destruction of pathogens as the compost ages. If one wants to be particularly cautious, one may allow the compost to age for two years after the pile has been completed, instead of the one year that is normally recommended.

In the words of Feachem et al., “*The effectiveness of excreta*

*treatment methods depends very much on their time-temperature characteristics. The effective processes are those that either make the excreta warm (55°C/131°F), hold it for a long time (one year), or feature some effective combination of time and temperature.”* The time/temperature factor of pathogen destruction is illustrated in Figure 7.7.

In short, the combined factors of temperature and time will do the job of turning your turds into tomatoes — so you can eat them.

## CONCLUSIONS

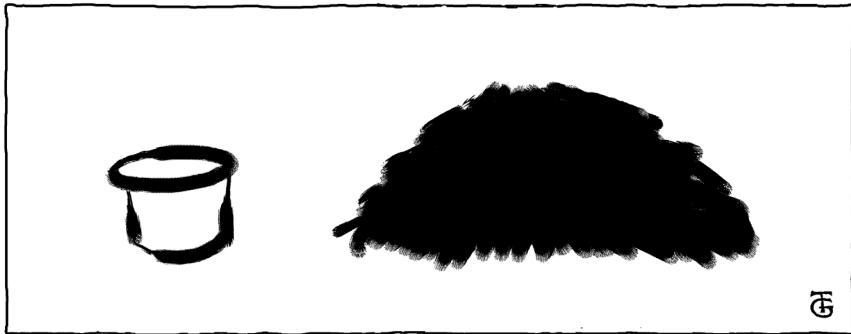
Humanure is a valuable resource suitable for agricultural purposes and has been recycled for such purposes by large segments of the world’s human population for thousands of years.

However, humanure contains the potential for harboring human pathogens, including bacteria, viruses, protozoa and parasitic worms or their eggs, and thereby can contribute to the spread of disease when improperly managed or when discarded as a waste material. When pathogenic raw humanure is applied to soil, pathogenic bacteria may continue to survive in the soil for over a year, and round-worm eggs may survive for many years, thereby maintaining the possibility of human reinfection for lengthy periods of time.

However, when humanure is composted, human pathogens are destroyed and the humanure is thereby converted into a hygienically safe form suitable for soil applications for the purpose of human food production.

Thermophilic composting requires no electricity and therefore no coal combustion, no acid rain, no nuclear power plants, no nuclear waste, no petrochemicals and no consumption of fossil fuels. The composting process produces no waste, no pollutants and no toxic by-products. Thermophilic composting of humanure can be carried out century after century, millennium after millennium, with no stress on our ecosystems, no unnecessary consumption of resources and no garbage or sludge for our landfills. And all the while it will produce a valuable resource necessary for our survival while preventing the accumulation of dangerous and pathogenic waste.





## THE TAO OF COMPOST

Organic material should be recycled by every person on the planet, and recycling should be as normal as brushing teeth or bathing. Organic materials can be collected by municipalities and composted at central composting facilities. This is now done in many parts of the world where food discards are composted for urban communities. Toilet materials are not yet being collected and centrally composted in very many places, although such collection will undoubtedly increase as time passes.

We can compost our own organic material in our own personal compost bins in our own backyards. This is already becoming commonplace and compost bins are now popping up in backyards everywhere like mushrooms after a rain. Composting need not cost money and it can be practiced by anyone in the world at probably any location where plants can grow. Therefore, it is important that we learn to understand what compost is and how it can be made.

It is also important that we understand how to compost our toilet materials in a safe and simple manner. A low-cost composting toilet system can be very useful as a back-up toilet in an emergency situation when electrical or water services are disrupted, or when the water supply is diminished as during a drought, when flushing drinking water down toilets becomes especially ridiculous. It can also be very useful in any area where water or electricity is scarce or non-exis-

tent, as well as in developing countries where there may be many people with little or no money to buy commercial composting toilets. Finally, a simple, low-cost composting toilet system is attractive to anyone seeking a low-impact lifestyle, and who is willing to make the minimal effort to compost their organic residues. This chapter details how to compost toilet materials by using a simple, easy, low or no-cost method called a sawdust toilet.

The organic materials our bodies excrete can be composted much the same as any apple core or potato peel — by being added to a compost pile. There are essentially two ways to do this. The first is to construct or purchase a toilet which deposits directly into a composting chamber. This is discussed and illustrated in Chapter 6. Such toilets must be properly managed if thermophilic conditions are desired; most commercial composting toilets do not achieve such conditions, and are not meant to.

The second, less expensive and simpler method is to use one's toilet as a collection device, much the same as any compost bucket, and then compost the contents in a separate compost pile. This simple technique can be done without unpleasant odors, and the toilet can be quite comfortably situated inside one's home. Moving toilet material to a compost bin, however, is an activity that many individuals have no interest in doing, not because it is a burdensome task — for a family of four it should involve a twenty minute trip to a compost bin about every week — but because it's *shit*, for God's sake.

The problem is not practical, it is psychological. Many people may consider the idea of composting their own excrement to be beneath them. In India, such a task was relegated to the "untouchables," the lowest caste of society. The act of carrying a container of one's own excrement to a recycling bin is an act of humility, and humility is sometimes in short supply. Eventually, toilets in general will be redesigned as collection devices and their contents will be collected and composted as a service by municipal workers. Until then, however, those of us who want to make compost rather than sewage must do it by our own humble selves.

## PRIMAL COMPOST

Try to imagine yourself in an extremely primitive setting, perhaps sometime around 10,000 B.C. Imagine that you're slightly more enlightened than your brutish companions and it dawns on you one day that your feces should be disposed of in a different manner.

Everyone else is defecating in the back of the cave, creating a smelly, fly-infested mess, and you don't like it.

Your first revelation is that smelly refuse should be deposited in one place, not spread around for everyone to step in, and it should be deposited away from one's living area. You watch the wild cats and see that they each go to a special spot to defecate. But the cats are still one step ahead of the humans, as you soon find out, because they cover their excrement.

When you've shat outside the cave on the ground in the same place several times, you see that you've still created a foul-smelling, fly-infested mess. Your second revelation is that the refuse you're depositing on the ground should be covered after each deposit. So you scrape up some leaves every time you defecate and throw them over the feces. Or you pull some tall grass out of the ground and use it for cover.

Soon your companions are also defecating in the same spot and covering their fecal material as well. They were encouraged to follow your example when they noticed that you had conveniently located the defecation spot between two large rocks, and positioned logs across the rocks to provide a convenient perch, allowing for care-free defecation.

A pile of dead leaves is now being kept beside the toilet area in order to make the job of covering it more convenient. As a result, the offensive odors of human feces and urine no longer foul the air. Instead, it's food scraps that are generating odors and attracting flies. This is when you have your third revelation: food scraps should be deposited on the same spot and covered as well. Every stinky bit of refuse you create is now going to the same place and is being covered with a natural material to eliminate odor. This hasn't been hard to figure out, it makes good sense, and it's easy to do.

You've succeeded in solving three problems at once: no more human waste scattered around your living area, no more food garbage and no more offensive odors assaulting your keen sense of smell and generally ruining your day. Eventually, you also begin to realize that the illnesses that were prone to spread through the group have subsided, a fact that you don't understand, but you suspect may be due to the group's new found hygienic practices.

Quite by accident, you've succeeded in doing one very revolutionary thing: *you've created a compost pile*. You begin to wonder what's going on when the pile gets so hot it's letting off steam. What you don't know is that you've done exactly what nature intended you to do

by piling all your organic refuse together, layered with natural, biodegradable cover materials. In fact, nature has "seeded" your excrement with microscopic creatures that proliferate in and digest the pile you've created. In the process, they heat the compost to such an extent that disease-causing pathogens resident in the humanure are destroyed. The microscopic creatures would not multiply rapidly in the discarded refuse unless you created the pile, and thereby the conditions which favor their proliferation.

Finally, you have one more revelation, a big one. You see that the pile, after it gets old, sprouts all kind of vibrant plant growth. You put two and two together and realize that the stinking refuse you carefully disposed of has been transformed into rich earth and ultimately into food. Thanks to you, humankind has just climbed another step up the ladder of evolution.

There is one basic problem with this scenario: it didn't take place 12,000 years ago — it's taking place now. Compost microorganisms are apparently very patient. Not much has changed since 10,000 B.C. in their eyes. The invisible creatures that convert humanure into humus don't care what composting techniques are used today anymore than they cared what techniques may have been used eons ago, so long as their needs are met. And those needs haven't changed in human memory, nor are they likely to change as long as humans roam the earth. Those needs include: 1) *temperature* (compost microorganisms won't work if frozen); 2) *moisture* (they won't work if too dry or too wet); 3) *oxygen* (they won't work without it); and 4) *a balanced diet* (otherwise known as balanced carbon/nitrogen). In this sense, compost microorganisms are a lot like people. With a little imagination, we can see them as a working army of microscopic people who need the right food, water, air and warmth.

The art of composting, then, remains the simple and yet profound art of providing for the needs of invisible workers so they work as vigorously as possible, season after season. And although those needs may be the same worldwide, the techniques used to arrive at them may differ from eon to eon and from place to place.

Composting differs from place to place because it is a bioregional phenomenon. There are thousands of geographic areas on the Earth each with their own unique human population, climatic conditions and available organic materials, and there will be potentially thousands of individual composting methods, techniques and styles. What works in one place on the planet for one group of people may not work for another group in another geographic location. For exam-

ple, we have lots of hardwood sawdust in Pennsylvania, but no rice hulls. Compost should be made in order to eliminate local waste and pollution as well as to recover resources, and a compost maker will strive to utilize in a wise and efficient manner whatever local organic resources are available.

### CLOSE ENCOUNTERS OF THE TURD KIND

Simple methods of collecting and composting humanure are sometimes called cartage systems or bucket systems, as the manure is carried to the compost bin, often in buckets or other waterproof vessels. People who utilize such simple techniques for composting humanure simply take it for granted that humanure recycling is one of the regular and necessary responsibilities for sustainable human life on this planet.

How it works is a model of simplicity. One begins by depositing one's organic refuse (feces and urine) into a plastic bucket, clay urn or other non-corrodible waterproof receptacle with about a five-gallon (20 liter) capacity. Food scraps may be collected in a separate receptacle, but can also be deposited into the toilet receptacle. A five-gallon capacity is recommended because a larger size would be too heavy to carry when full. If a full five-gallon container is still too heavy for someone to carry, it can be emptied when only half full.

The contents of the toilet are *always* kept covered with a clean, organic *cover material* such as rotted sawdust, peat moss, leaf mould, rice hulls or grass clippings, in order to prevent odors, absorb urine, and eliminate any fly nuisance. Urine is deposited into the same receptacle, and as the liquid surface rises, more cover material is added so that a clean layer of organic material covers the toilet contents *at all times*.

A lid is kept on the toilet receptacle when not in use. The lid need not be air-tight; a standard, hinged toilet seat is quite suitable. The lid does not necessarily prevent odor from escaping, and it does not necessarily prevent flies from gaining access to the toilet contents. Instead, the *cover material does*. The cover material acts as an organic lid or a *biofilter*; the physical lid or toilet seat is used primarily for convenience and aesthetics. Therefore, the choice of organic cover material is very important and a material that has some moisture content, such as rotted sawdust, works well. This is not kiln-dried sawdust from a carpenter shop. It is sawdust from a sawmill where trees are cut into boards. Such sawdust is both moist and biologically

active and makes a very effective biofilter. Kiln-dried sawdust is too light and airy to be a 100% effective biofilter, unless partially rehydrated. Furthermore, kiln-dried sawdust from wood-working shops may contain hazardous chemical poisons if “pressure-treated” lumber is being used there.

During a cold winter, an outdoor pile of sawdust will freeze solid and should be covered or insulated in some manner. Otherwise, feedsacks filled with sawdust stored in a basement will work as an alternative, as will peat moss and other cover materials stored indoors.

The system of using an organic cover material in a toilet receptacle works well enough in preventing odors to allow the toilet to be indoors, year round. In fact, a full bucket with adequate and appropriate cover material, and no lid, can be set on the kitchen table without emitting unpleasant odors (take my word for it). An indoor sawdust toilet should be designed to be as warm, cozy, pleasant and comfortable as possible. A well-lit, private room with a window, a standard toilet seat, a container of cover material and some reading material will suffice.

Full buckets are carried to the composting area and deposited on the pile (you'll know that a bucket is full enough to empty when you have to stand up to take a shit). Since the material must be moved from the toilet room to an outdoor compost pile, the toilet room should be handy to an outside door. If you are designing a sawdust toilet in a new home, situate the toilet room near a door that allows direct access to the outside.

It is best to dig a slight depression in the top center of the compost pile in the outdoor compost bin, then deposit the fresh toilet material there, in order to keep the incoming humanure in the hotter center of the pile. This is easily achieved by raking aside the cover material on top of the pile, depositing the toilet contents in the resulting depression, and then raking the cover material back over the fresh deposit. The area is then immediately covered with additional clean, bulky, organic material such as straw, leaves or weeds, in order to eliminate odors and to trap air as the pile is built.

The bucket is then thoroughly scrubbed with a small quantity of water, which can be rain water or graywater, and biodegradable soap, if available or desired. A long-handled toilet brush works well for this purpose. Often, a simple but thorough rinsing will be adequate. Rain water or wastewater is ideal for this purpose as its collection requires no electricity or technology. The soiled water is then

poured on the compost pile.

It is imperative that the rinse water not be allowed to pollute the environment. The best way to avoid this is to put the rinse water on the compost pile, as stated. However, the rinse water can be poured down a drain into a sewer or septic system, or drained into an artificial wetland. It can also be poured at the base of a tree or shrub that is designated for this purpose. Such a tree or shrub should have a thick layer of organic material — a *biological sponge* — at its base and be staked or fenced to prevent access by children or pets. Under no circumstances should the rinse water be flung aside nonchalantly. This can be a weak link in this simple humanure recycling chain and it provides the most likely opportunity for environmental contamination. Such contamination is easy to avoid through considerate, responsible management of the system. Finally, never use chlorine to rinse a compost receptacle. Chlorine is a chemical poison that is detrimental to the environment and is totally unnecessary for use in any humanure recycling system. Simple soap and water is adequate.

After rinsing or washing, the bucket is then replaced in the toilet area. The inside of the bucket should then be dusted with sawdust, the bottom of the empty receptacle should be primed with an inch or two of sawdust, and it's once again ready for use. After about ten years, the plastic bucket may begin to develop an odor,

#### **YARDS AND GARDENS: TRANSLATING AMERICAN INTO ENGLISH**

In the United States, a "yard" is a grassy area surrounding a house; the term is equivalent to the English term "garden." That grassy area may contain trees, shrubs or flowers. If it is located in front of the house, it is called the "front yard." Behind the house, it is the "back yard." Beside the house, it is the "side yard." An American "garden" is a plot of vegetables, often located within the yard. An American garden can also be a flower garden or fruit garden; some American gardens contain flowers, fruits and vegetables. In the UK, the green area around a house is called the "garden," whether it contains vegetables, flowers or nothing but mowed grass. English homes do not have "yards." So the term "back yard composting," translated to UK English, would be "back garden composting."

#### **SAWDUST TOILET STATISTICS**

One hundred pounds of human body weight will fill approximately three gallons (.4 cubic feet, 693 cubic inches, or approximately 11 liters) in a sawdust toilet per week - this volume includes the sawdust cover material. One hundred pounds of human body weight will also require approximately 3 gallons of semi-dry, deciduous, rotting sawdust per week for use as a cover material in a toilet. This amounts to a requirement of approximately 20 cubic feet of sawdust cover material per one hundred pounds of body weight per year for the proper functioning of a sawdust toilet. Human excrement tends to add weight rather than volume to a sawdust toilet as it is primarily liquid and fills the air spaces in the sawdust. Therefore, for every gallon of sawdust-covered excrement collected in a sawdust toilet, nearly a gallon of cover material will need to be used.

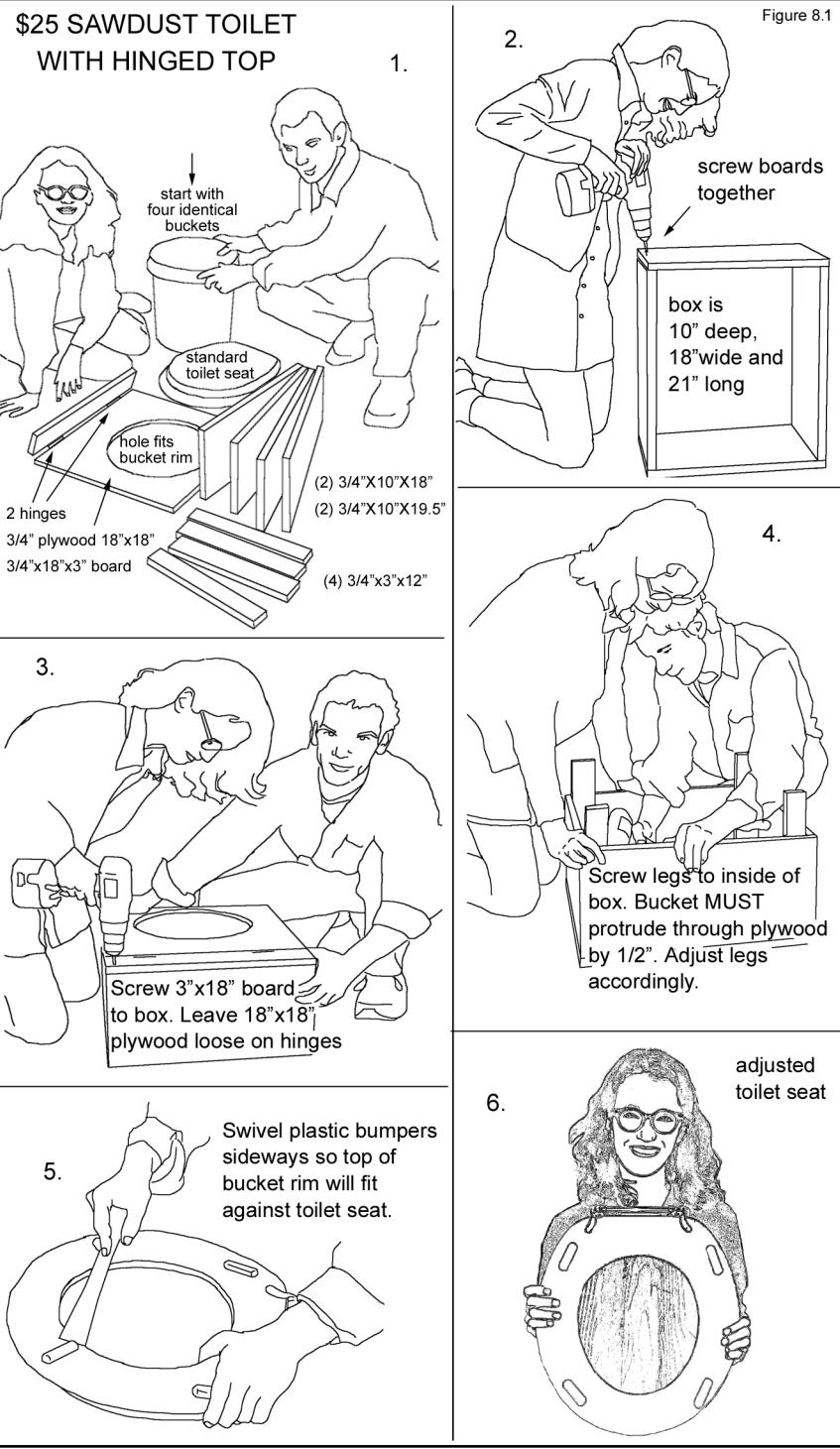


Figure 8.1

### \$25 SAWDUST TOILET WITH HINGED TOP (CONT.)



Mark holes for toilet seat attachment.

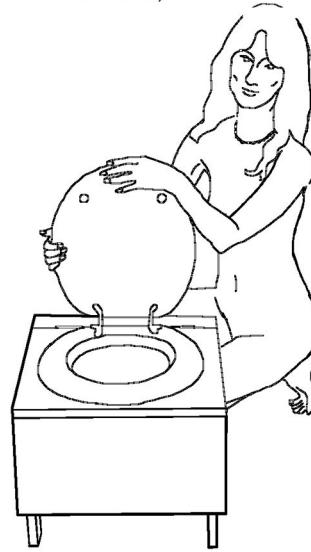
A hinged sawdust toilet box will be 18" wide by 21" long. Get two boards 3/4"x10"x18" and two 3/4"x10"x19.5". Get two hinges, one piece of 3/4"x18"x18" plywood and one 3/4"x3"x18". Hinge the plywood to the 3"x18" piece.

Cut a hole in the larger piece of plywood to fit the top of the 5 gallon bucket. Set the hole only 1 & 1/2 inches back from the front edge of the plywood. Start with four identical buckets so you have extras. Buy a standard toilet seat somewhere.

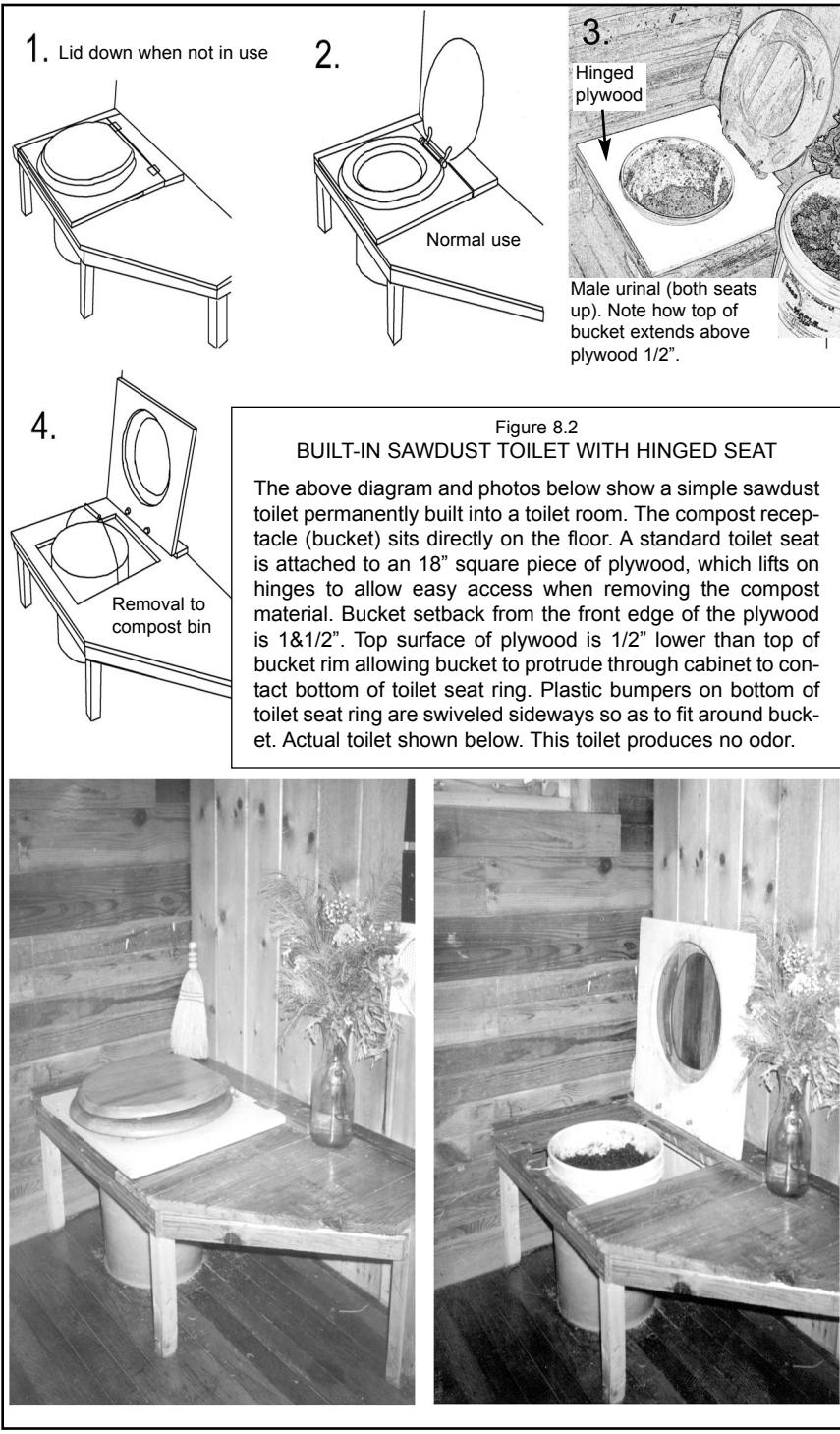


Drill holes.

When screwing the legs to the inside of the box, make sure the top edge of the box will sit about 1/2" below the top edge of the bucket (the top of the bucket rim should protrude through the box by 1/2"). This allows the bucket rim to sit tight against the underside of the toilet seat (which is why the toilet seat bumpers are pried loose and swiveled to one side, as shown in #5 and #6).



9. Attach your seat. Stain, varnish or paint the wood. You now have a compost toilet!



even after a thorough washing. Replace odorous buckets with new ones in order to maintain an odor-free system. The old buckets will lose their odor if left to soak in clean, soapy water for a lengthy period (perhaps weeks), rinsed, sun-dried and perhaps soaked again, after which they can be used for utility purposes (or, if you really have a shortage of buckets, they can be used in the toilet again).

Here's a helpful hint: when first establishing such a toilet system, it's a good idea to acquire at least *four* five-gallon buckets with lids, that are *exactly the same*, and more if you intend to compost for a large number of people. Use one under the toilet seat and the other three, with lids, set aside in the toilet room, empty and waiting. When the first becomes full, take it out of the toilet, put a lid on it, set it aside, and replace it with one of the empty ones. When the second one fills, take it out, put the other lid on it, set it aside, and replace it with the other empty one. Now you have two full compost buckets, which can be emptied at your leisure, while the third is in place and ready to be used. This way, the time you spend emptying compost is cut in half, because it's just as easy to carry two buckets to the compost pile as one. Furthermore, you potentially have a 20-gallon toilet capacity at any one time instead of just five gallons. You may find that extra capacity to come in very handy when inundated with visitors.

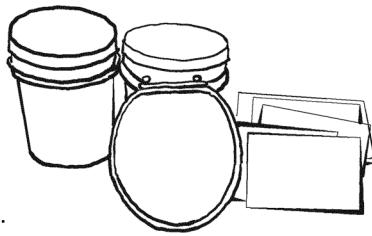
Why should all of the buckets be exactly the same? If you build a permanent toilet cabinet, the top of the bucket should protrude through the cabinet to contact the bottom of a standard toilet seat. This ensures that all organic material goes into the container, not over its edge. Although this is not usually a problem, it can be with young children who may urinate over the top of a bucket receptacle when sitting on a toilet. A good design will enable the bucket to fit tightly through the toilet cabinet as shown in Figures 8.1 and 8.4. Since all plastic buckets are slightly different in height and diameter, you should build your toilet cabinet to fit one size bucket. You should have extra identical buckets when backup capacity is needed to accommodate large numbers of people.

Theoretically, with enough containers, a sawdust toilet system can be used for any number of people. For example, if you are using a sawdust toilet in your home, and you are suddenly visited by thirty people all at once, you will be very happy to have empty containers ready to replace the ones that fill up. You will also be very happy that you will not have to empty any compost containers until after your company leaves, because you can simply set them out of the way, with lids, in the toilet room as they fill up, and then empty them

Figure 8.3

### SAWDUST TOILET SIMPLE LIFT-OFF BOX

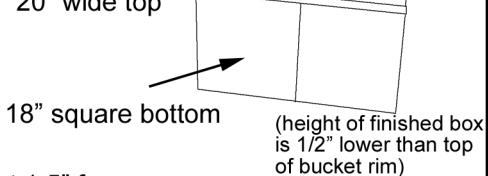
1. Obtain buckets first. Build toilet to fit buckets. Use a standard toilet seat. Start with four buckets, with lids, that are exactly the same.



2. Assemble sides  
of box with  
screws.



3. Attach top  
boards



4. Set bucket 1.5" from  
front of box, center it and  
mark hole.



5. Cut hole.

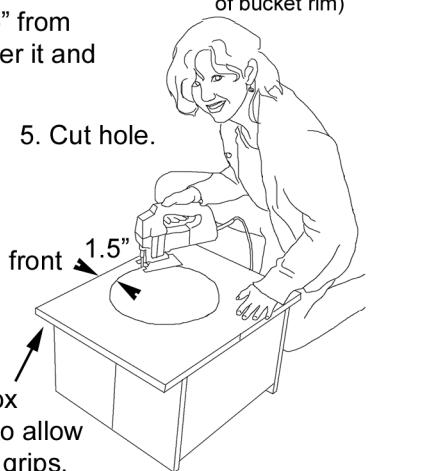
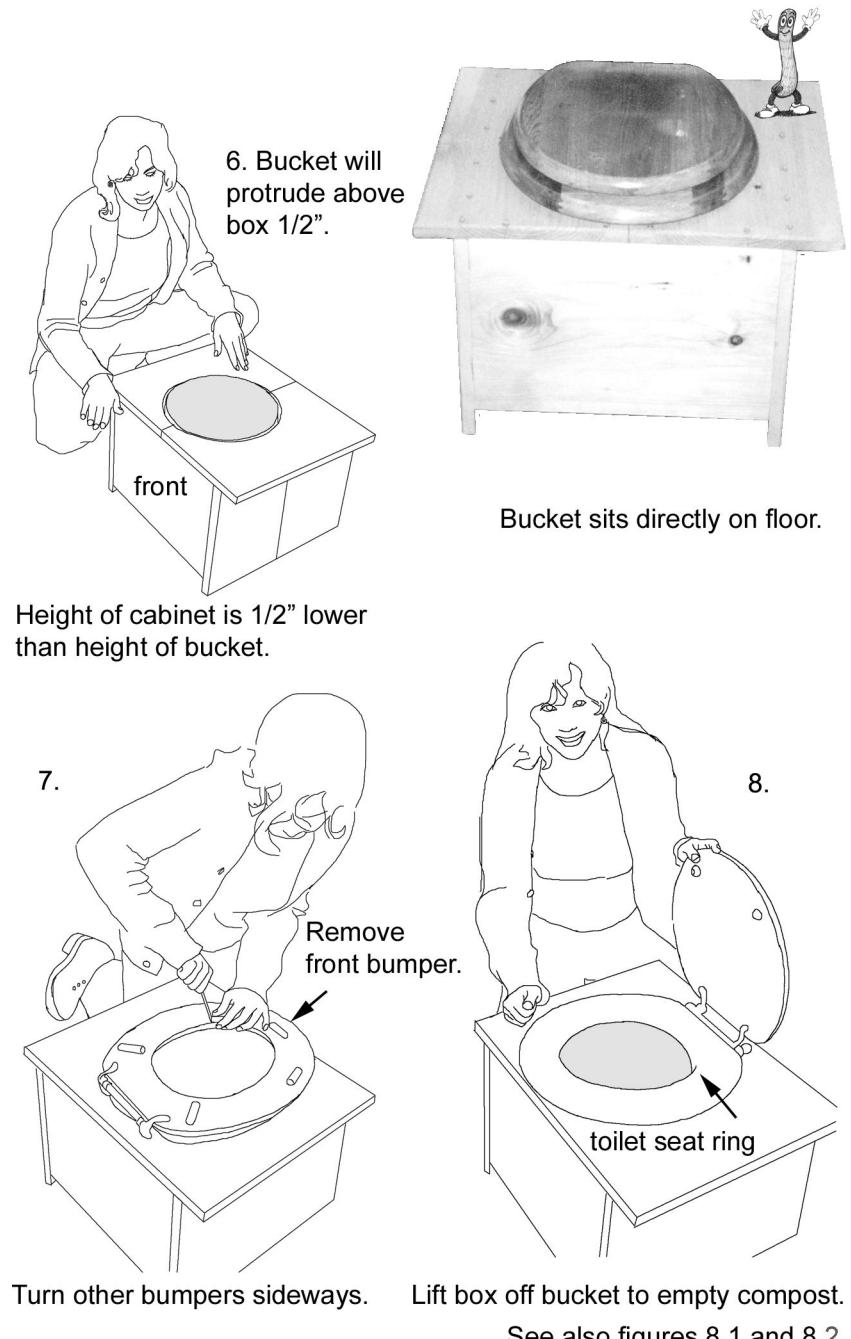


Figure 8.3 SAWDUST TOILET LIFT-OFF BOX (CONT.)



Anonymous Reader-Contributed Photos of Owner-Built Toilets

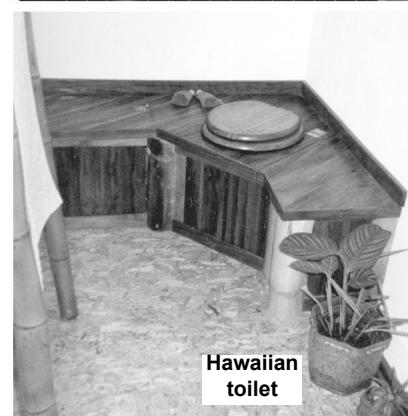
Canadian  
toilet



use of old toilet tank  
for sawdust storage



Hawaiian  
toilet





### DO'S AND DON'TS OF A THERMOPHILIC TOILET COMPOSTING SYSTEM

DO — Collect urine, feces, and toilet paper in the same toilet receptacle. Urine provides essential moisture and nitrogen.		DON'T — Segregate urine or toilet paper from feces.
DO — Keep a supply of clean, organic cover material handy to the toilet at all times. Rotting sawdust, peat moss, leaf mould, and other such cover materials prevent odor, absorb excess moisture, and balance the C/N ratio.		DON'T — Turn the compost pile if it is being continuously added to and a batch is not available. Allow the active thermophilic layer in the upper part of the pile to remain undisturbed.
		DON'T — Use lime or wood ashes on the compost pile. Put these things directly on the soil.
		DON'T — Expect thermophilic activity until a sufficient mass has accumulated.
		DON'T — Deposit anything smelly into a toilet or onto a compost pile without covering it with a clean cover material.
DO — Deposit humanure into a depression in the top center of the compost pile, not around edges.		DON'T — Allow dogs or other animals to disturb your compost pile. If you have problems with animals, install wire mesh or other suitable barriers around your compost, and underneath, if necessary.
DO — Add a mix of organic materials to the humanure compost pile, including <i>all</i> food scraps.		DON'T — Segregate food items from your humanure compost pile. Add all organic materials to the same compost bin.
		DON'T — Use the compost before it has fully aged. This means one year after the pile has been constructed, or two years if the humanure originated from a diseased population.
		DON'T — Worry about your compost. If it does not heat to your satisfaction, let it age for a prolonged period, then use it for horticultural purposes.

the next day.

Experience has shown that 150 people will require four five-gallon containers during a serious party. Therefore, always be prepared for the unexpected, and maintain a reserve toilet capacity at all times by having extra toilet receptacles available, as well as extra cover material. Incidentally, for every full container of compost material carried out of a toilet room, a full, same-sized container of cover material will need to be carried in. You cannot successfully use this sort of toilet without an adequate supply of appropriate cover material.

Expecting five hundred people for a major gathering out in the woods? Sawdust toilets will work fine, as long as you keep enough buckets handy, as well as adequate cover materials. With a system set up to compost the material and some volunteers to manage it all, you will collect a lot of valuable soil nutrients.

The advantages of a sawdust toilet system include low financial start-up cost in the creation of the facilities, and low, or no energy consumption in its operation. Also, such a simple system, when the refuse is thermophilically composted, has a low environmental cost as little or no technology is required for the system's operation and the finished compost is as nice and benign a material as humus can ever hope to be. No composting facilities are necessary in or near one's living space, although the toilet can and should be inside one's home and can be quite comfortably designed and totally odor-free.

No electricity is needed and no water is required except a small amount for cleaning purposes. One gallon of water can clean two five gallon buckets. It takes one adult two weeks to fill two five gallon toilet buckets with humanure and urine, including cover material. This requires one gallon of cleaning water for every two weeks of sawdust toilet use as opposed to the standard thirty gallons per person per day used to flush a water toilet.

The compost, if properly managed, will heat up sufficiently for sanitation to occur, thereby making it useful for gardening purposes. The composting process is fast, i.e., the humanure is converted quickly — within a few days if not frozen — into an inoffensive substance that will not attract flies. In cold winter months the compost may simply freeze until spring thaw, then heat up. If the compost is unmanaged and does not become thermophilic, the compost can simply be left to age for a couple of years before horticultural use. In either case, a complete natural cycle is maintained, unbroken.

## THE COMPOST BINS

A sawdust toilet requires three components: 1) the toilet receptacle; 2) cover materials; and 3) a compost bin system. The system will *not* work without all three of these components. The toilet is only the collection stage of the process. Since the composting takes place *away* from the toilet, the compost bin system is important.

1) *Use at least a double-chambered, above-ground compost bin.* A three-chambered bin is recommended. Deposit in one chamber for a period of time (e.g., a year), then switch to another for an equal period of time.

2) *Deposit a good mix of organic material into the compost pile,* including kitchen scraps. It's a good idea to put all of your organic material into the same compost bin. Pay no attention to those people who insist that humanure compost should be segregated from other compost. They are people who do not compost humanure and don't know what they're talking about.

3) *Always cover humanure deposits in the toilet with an organic cover material* such as sawdust, leaf mould, peat moss, rice hulls, ground newsprint, finely shredded paper or what have you. *Always cover fresh deposits on the compost pile with coarse cover materials* such as hay, weeds, straw, grass clippings, leaves or whatever is available. Make sure that enough cover material is applied so there is neither excess liquid build-up in the toilet nor offensive odors escaping either the toilet or the compost pile. The trick to using cover material is quite simple: *if it smells bad or looks bad, cover it until it does neither.*

4) *Keep good access to the pile* in order to rake the top somewhat flat, to apply bulky cover material when needed, to allow air access to the pile, and to monitor the temperature of the pile. The advantage of aerobic composting, as is typical of an above-ground pile, over relatively anaerobic composting typical of enclosed composting toilets, is that the aerobic compost will generate higher temperatures, thereby ensuring a more rapid and complete destruction of potential human pathogens.

The disadvantages of a collection system requiring the regular transporting of humanure to a compost pile are obvious. They include the inconvenience of: 1) carrying the material to the compost pile; 2) keeping a supply of organic cover material available and handy to the toilet; 3) maintaining and managing the compost pile itself. If one can handle these simple tasks, then one need never worry about having a functioning, environmentally friendly toilet.

## NORMAL COMPOSTING BIN SEQUENCE

It's very important to understand that *two* factors are involved in destroying potential pathogens in humanure. Along with heat, the *time* factor is important. Once the organic material in a compost pile has been heated by thermophilic microorganisms, it should be left to age or "season." This part of the process allows for the final decomposition to take place, decomposition that may be dominated by fungi and macroorganisms such as earthworms and sowbugs. Therefore, a good compost system will utilize at least two composting bins, one to fill and leave to age, and another to fill while the first is aging. A three-binned composting system is even better, as the third bin provides a place to store cover materials, and separates the active bins so there is no possible accidental transfer of fresh material to an aging bin.

When composting humanure, fill one bin first. Start the compost pile by establishing a thick layer of coarse and absorbent organic material on the bottom of the bin. This is called a "biological sponge." Its purpose is to act as a leachate absorption barrier. The sponge may be an 18 inch *or more* layer of hay or straw, grass clippings, leaves, and/or weeds. Place the first container of the humanure/sawdust mix from the toilet directly on the top center of the sponge. Cover immediately with more straw, hay, weeds, or leaves — the cover acts as a natural "biofilter" for odor prevention, and it causes air to become trapped in the developing compost pile, making physical turning of the pile for aeration unnecessary. A standard bin size is about 5 feet square and 4 feet high (1.6 meters square and 1.3 meters high).

Continue in this manner until the bin is full, which is quite likely to take a year, being sure to add to this bin as much of the other organic material you produce as is practical. There is no need to have any other compost piles — one is enough for everything produced by the humans in your household. If you have small animals such as chickens or rabbits, their manure can go into the same compost pile. Small dead animals can also be added to the compost pile.

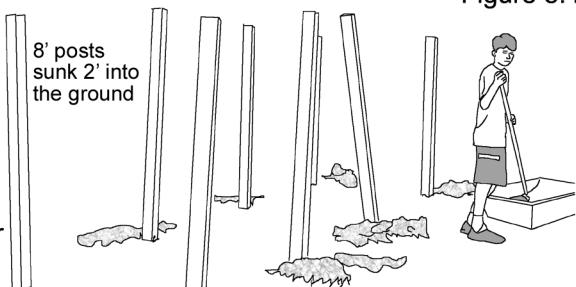
You need to do nothing special to prepare material for adding to the compost pile. You do not need to chop up vegetables, for example. Just chuck it all in there. Most of the things compost educators tell you cannot be composted *can* be composted in your humanure compost pile (such as meat, fats, oils, citrus fruits, animal mortalities, etc.). Add it all to the same compost pile. Anything smelly that may

Figure 8.4

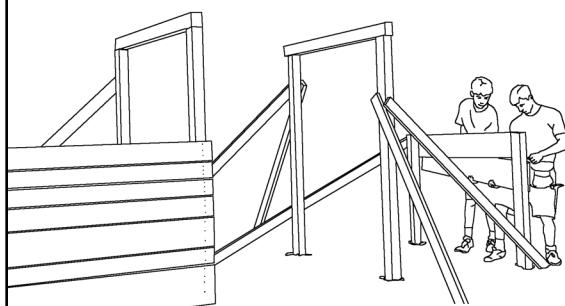
HOW TO CONSTRUCT

## THE HUMANURE HACIENDA

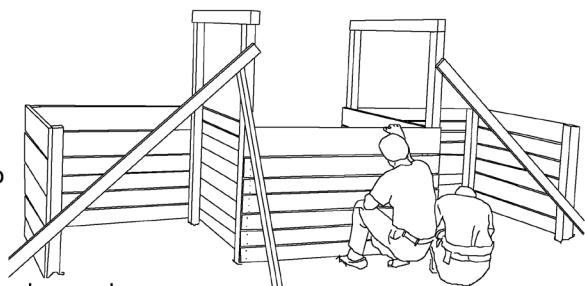
1. Dig 24" deep holes, drop in (8) 4x4 locust (or other suitable) posts, back fill with soil mixed with concrete. Posts are about 5' (1.6 meters) apart. Leave four center posts high. Cut four outer posts to a height of about 4'.



2. Plumb and brace posts. Nail 4x4 header across higher center posts.



3. Screw 1" thick, rough sawn black locust (or other suitable) lumber to posts as shown. Leave small gap between boards and about 2" between bottom board and ground.



4. Cut rafters and install in a simple gable roof design. All the lumber for the roof can be recycled. The posts and side walls should be rot resistant lumber, but not lumber treated with toxic chemicals. It would be better to use scrap lumber for the sidewalls and replace it periodically than to use toxic lumber. The roofed center section will hold cover materials and will keep them dry, protected and unfrozen. The roof will also collect rain water, which should be used to clean compost buckets when not frozen.

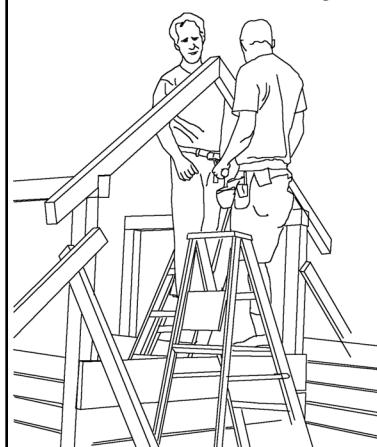


Figure 8.4

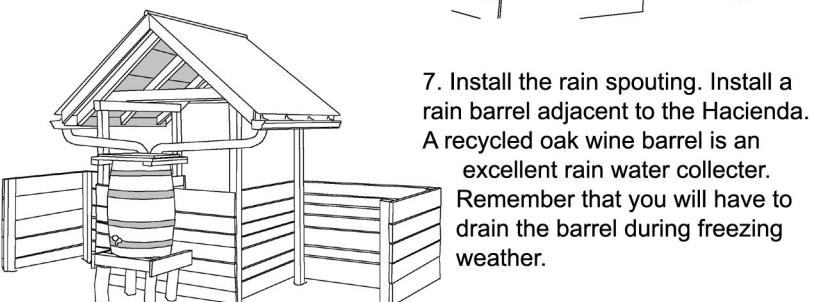
## HUMANURE HACIENDA (cont.)



5. Nail sheathing boards to roof rafters. Make sure rafter tails have plumb cuts so a fascia board can be attached.



6. Install fascia boards, then the finished roofing. Recycled slate makes an excellent roofing material.



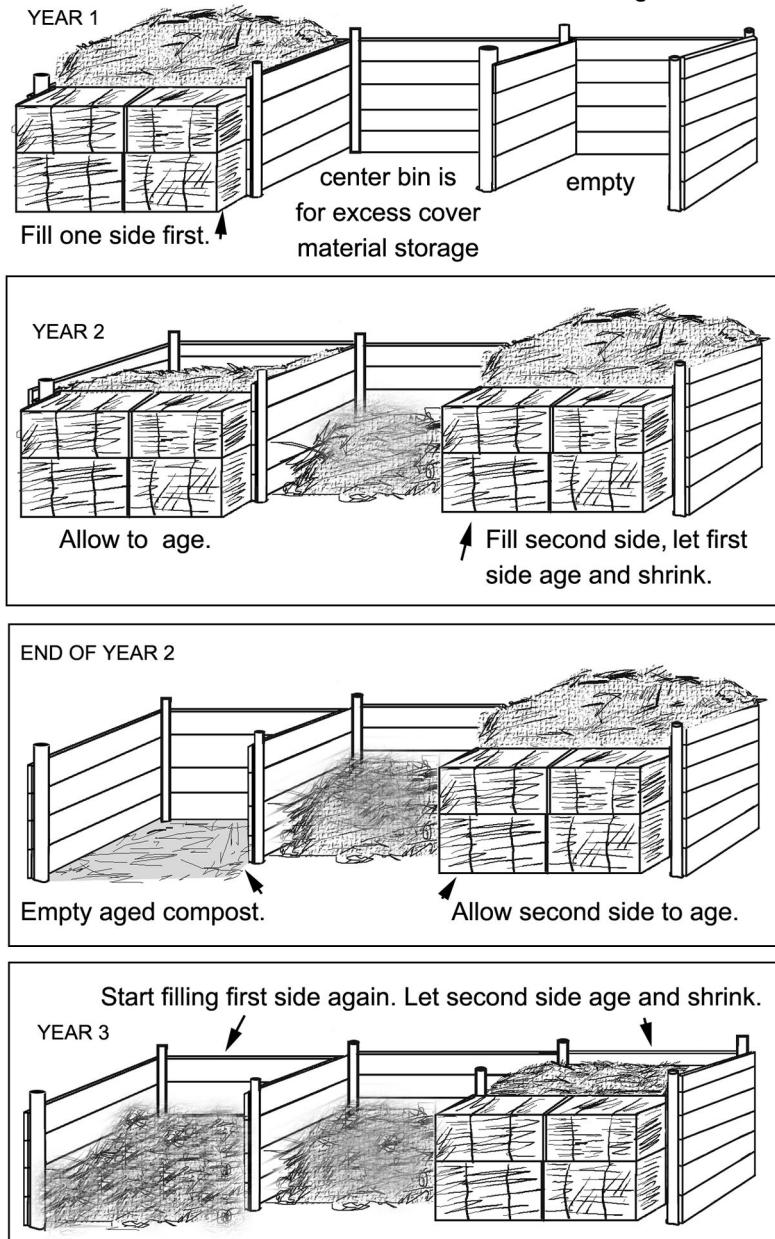
7. Install the rain spouting. Install a rain barrel adjacent to the Hacienda. A recycled oak wine barrel is an excellent rain water collector. Remember that you will have to drain the barrel during freezing weather.

The author's Humanure Hacienda, shown at right, is expected to last a lifetime. The rain water system makes cleaning compost buckets very convenient spring, summer and fall. The center roof also keeps bales of hay and straw dry and available for use throughout the winter.



## THE CEASELESS CYCLE OF COMPOST MAKING

Figure 8.5



If you want your compost to age for two years instead of one, add a fourth bin to the system. Turning the compost is not necessary (read Chapter 3). A roof over the center bin will keep the cover material dry and unfrozen in the winter months in cold climates (see figure 8.4).

attract flies should be dug into the top center of the pile. Keep a shovel or pitchfork handy for this purpose and use the tool *only* for the compost. Keep a clean cover material over the compost at all times and don't let your compost pile become shaped like the Matterhorn — keep it somewhat flattened so nothing rolls off.

When you have a sudden large quantity of cover material available, such as an influx of grass clippings when the lawn is mowed, weeds from the garden, or leaves in the fall, place them in the center bin for storage and use them to cover humanure deposits as you need them. It is assumed that you do not use any poisonous chemicals on your lawn. If you do, bag the lawn clippings, take them to a toxic waste dump, and on the way, reflect upon the folly of such behavior. Do not put poisoned grass clippings in your compost pile.

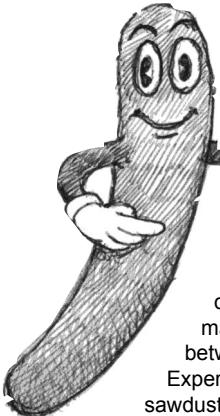
Filling the first bin should take a year — that's how long it takes us, a family, usually of four, with a lot of visitors. We have used this system for 26 continuous years at the time of this writing and every year at the summer solstice (on or about June 20th) we start a new compost pile. During March, April and May, the pile always *looks* like it is already full and can't take any more material, but it always does. This is due to the constant shrinkage of the compost pile that takes place as summer approaches. When the pile is finally completed, it is covered over with a thick layer of straw, leaves, grass clippings or other clean material (without weed seeds) to insulate it and to act as a biofilter; then it is left to age (see photo, page 175).

At this time, the second bin is started following the same procedure as the first — starting with a biological sponge. When the second chamber is nearly full (a year later), the first one can begin to be emptied onto the garden, berries, orchard or flower beds. If you're not comfortable using your compost for gardening purposes for whatever reason, use it for flowers, trees or berries.

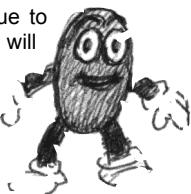
A compost pile can accept a huge amount of refuse, and even though the pile may seem to be full, as soon as you turn your back it will shrink down and leave room for more material. One common concern among neophyte humanure composters is the pile looking like it's filling up too fast. More than likely, the compost pile will keep taking the material as you add it because the pile is continually shrinking. If, for some reason, your compost pile does suddenly fill up and you have no where to deposit the compost material, then you will simply have to start a new compost bin. Four wooden pallets on edge will make a quick compost bin in an emergency.

The system outlined above will not yield any compost until

### A TIP FROM TOMMY TURD



Sawdust works best in compost when it comes from logs, not kiln-dried lumber. Although kiln-dried sawdust (from a wood-working shop) will compost, it is a dehydrated material and will not decompose as quickly as sawdust from fresh logs, which are found at sawmills. Kiln-dried sawdust may originate from "pressure-treated" lumber, which usually is contaminated with chromated copper arsenate, a known cancer-causing agent, and a dangerous addition to any backyard compost pile. Sawdust from logs can be an inexpensive and plentiful local resource in forested areas. It should be stored outside where it will remain damp and continue to decompose. Although some think sawdust will make soil acidic, a comprehensive study between 1949 and 1954 by the Connecticut Experiment Station showed no instance of sawdust doing so.<sup>1</sup>



<sup>1</sup>See: Rodale, *The Complete Book of Composting*, 1960, p. 192.

two years after the process has started (one year to build the first pile and an additional year for it to age). However, after the initial two year start-up period, an ample amount of compost will be available on an annual basis.

What about leachate, or noxious liquids draining from the pile into the environment? First, compost *requires* a lot of moisture; evaporated moisture is one of the main reasons why compost shrinks so much. Compost piles are not inclined to *drain* moisture unless subjected to an excessive amount of rain. Most rainwater is absorbed by the compost, but in heavy rainfall areas a roof or cover can be placed over the compost pile at appropriate times in order to prevent leaching. This roof can be as simple as a piece of plastic or a tarp. Second, a thick biological sponge should be layered under the compost before the pile is built. This acts as a leachate barrier.

If these two factors aren't effective enough, it would be a simple matter to place a layer of plastic underneath the compost pile, under the biological sponge, before the pile is built. Fold the plastic so that it collects any leachate and drains into a sunken five gallon bucket. If leachate collects in the bucket, pour it back over the compost pile. The interface between the compost pile and the soil acts as a corridor for soil organisms to enter the compost pile, however, and plastic will prevent that natural migration. Nevertheless, the plastic *can* provide simple and effective leachate prevention, if needed.

## PATHOGENIC POPULATIONS AND A 2-YEAR RETENTION TIME

Fecophobes, as we have seen throughout this book, believe that all human excrement is extremely dangerous and will cause the end of the world as we know it if not immediately flushed down a toilet. Some insist that humanure compost piles must be turned frequently — to ensure that all parts of the pile are subjected to the internal high temperatures.

The only problem with that idea is that most people produce organic refuse a little at a time. For example, most people defecate once a day. A large amount of organic material suitable for thermophilic composting is therefore usually not available to the average person. As such, we who make compost a daily and normal part of our lives tend to be “continuous composters.” We add organic material continuously to a compost pile, and almost never have a large “batch” that can be flipped and turned all at once. In fact, a continuous compost pile will have a thermophilic *layer*, which will be located usually in the top two feet or so of the pile. If you turn the compost pile under these conditions, that layer will become smothered by the thermophilically “spent” bottom of the pile, and all thermophilic activity will grind to a halt.

In healthy human populations, therefore, turning a continuous compost pile is not recommended. Instead, all humanure deposits should be deposited in the top center of the compost pile in order to feed it to the hot area of the compost, and a thick layer of insulating material (e.g., hay) should be maintained over the composting mass. Persons who have doubts about the hygienic safety of their finished humanure compost are urged to either use the compost for non-food crops or orchards, or have it tested at a lab before using on food crops.

On the other hand, one may have the need to compost humanure from a population with known disease problems. If the organic material is available in *batches*, then it can be turned frequently during the thermophilic stage, if desired, in order to enhance pathogen death. After the thermophilic stage, the compost can be left to age for at least a year. Refer to Chapter 3 for more information on turning compost piles.

If the organic material from a diseased population is available only on a continuous basis, and turning the pile, therefore, is counterproductive, an *additional* year-long curing period is recommended. This will require one more composting bin in addition to the two

**ANOTHER TIP FROM  
TOMMY TURD**



**THE SECRET TO COMPOSTING  
HUMANURE IS TO KEEP IT COVERED.**

Always thoroughly cover toilet deposits with a clean, organic cover material such as rotting sawdust, peat moss, leaf mould, rice hulls, or other suitable material to prevent odor, absorb urine and balance the nitrogen.

Always cover toilet deposits again, after adding them to the compost pile, with a clean cover material such as hay, straw, weeds, grass clip-

pings, leaves or other suitable material in order to prevent odors and flies, to create air spaces in the compost pile and to balance the nitrogen.

Such cover materials also add a blend of organic materials to the compost, and the variety supports a healthier microbial population.



already in use. After the first is filled (presumably for a year), it is left to rest *for two years*. The second is filled during the second year, then it is left to rest for two years. The third is filled during the third year. By the time the third is filled, the first has aged for two years and should be pathogen-free and ready for agricultural use. This system will create an initial lag-time of three years before compost is available for agricultural purposes (one year to build the first pile, and two more years retention time), but the extra year's retention time will provide added insurance against lingering pathogens. After the third year, finished compost will be available on a yearly basis. Again, if in doubt, either test the compost for pathogens in a laboratory, or use it agriculturally where it will not come in contact with food crops.

### ANALYSES

After 14 years of humanure composting I analyzed my garden soil, my yard soil (for comparison), and my compost, each for fertility and pH, using LaMotte test kits from the local university.<sup>1</sup> I also sent samples of my feces to a local hospital lab to be analyzed for indicator parasitic ova or worms. That was back in 1993.

The humanure compost proved to be adequate in nitrogen (N), rich in phosphorus (P) and potassium (K), and higher than either the garden or the yard soil in these constituents as well as in various beneficial minerals. The pH of the compost was 7.4 (slightly alkaline), but no lime or wood ashes had been added during the composting process. This is one reason why I don't recommend adding

lime (which raises the pH) to a compost pile. A finished compost would ideally have a pH around, or slightly above, 7 (neutral).

The garden soil was slightly lower in nutrients (N, P, K) than the compost, and the pH was also slightly lower at 7.2. I had added lime and wood ashes to my garden soil over the years, which may explain why it was slightly alkaline. The garden soil, however, was still significantly higher in nutrients and pH than the yard soil (pH of 6.2), which remained generally poor.

My stool sample was free of pathogenic ova or parasites. I used my own stool for analysis purposes because I had been exposed to the compost system and the garden soil longer than anyone else in my family by a number of years. I had freely handled the compost, with bare hands, year after year, with no reservations. I repeated the stool analysis a year later, after 15 years of exposure, then 11 years later, after 26 years of exposure, again with negative results. Hundreds of people had used my compost toilet over the years, prior to these tests.

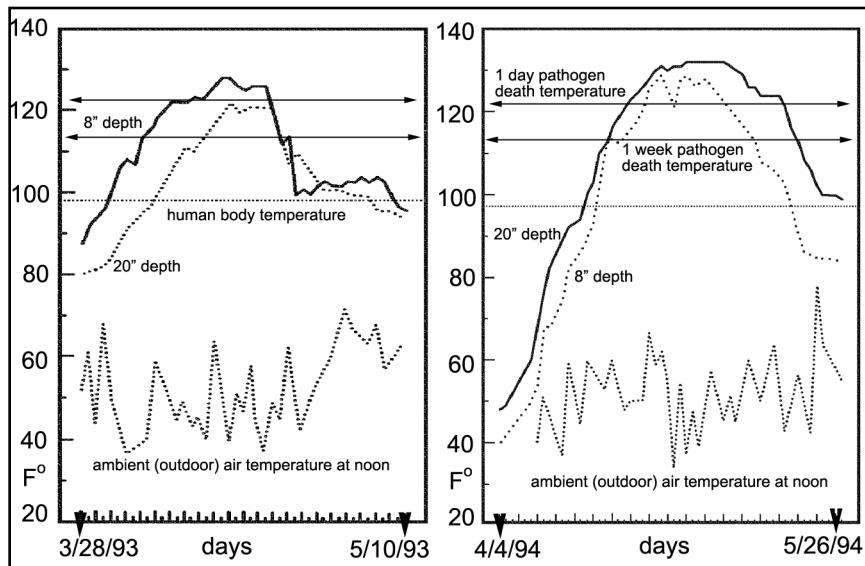
These results indicate that humanure compost is a good soil builder, and that no intestinal parasites were transmitted from the compost to the compost handler after 26 years of continuous, unrestricted use in the United States.

Over the entire 26-year period, most of the humanure compost my family has produced has been used in our food garden. We have raised a lot of food with that compost, and a crop of lovely and healthy children with that food.

Some may surmise that the Ova & Parasite lab analyses I had done were pointless. They didn't prove anything because there may not have been any contamination by intestinal parasites in the compost to begin with. If, after 26 years and literally hundreds of users, no such contaminants made their way into my compost, then that's important information. This suggests that the fears of humanure compost are grossly overblown. The point is that my compost has not created any health problems for me or my family, and that's a very important point, one that the fecophobes should take note of.

## MONITORING COMPOST TEMPERATURE

Back in 1993 I charted the temperature of my thawing spring compost piles for two years in a row. Over the winter, the compost had frozen solid as a shitcicle and I wanted to see what was happening after the piles thawed out. The compost consisted primarily of



**Figure 8.7  
TEMPERATURE CURVES OF FROZEN HUMANURE COMPOST PILES,  
AT 8" AND 20" DEPTHS, AFTER SPRING THAW**

The above compost piles were situated outdoors, in wooden bins, on bare soil. The compost was unturned and not manually aerated in any way. No compost starters were used. Ingredients included humanure, urine, food scraps, hay, weeds, and leaves (and some chicken manure on the 1994 compost). The compost was frozen solid through the winter, but exhibited the above temperature climb after thawing in the spring. Fresh material was added to the compost pile regularly while these temperatures were being recorded on unmoved thermometers. The hot area of the compost pile remained in the upper section of the compost as the pile continued to be built during the following summer. In the fall, the entire compost pile cooled down, finally freezing and becoming dormant until the following spring, when it regained consciousness and heated again. It is evident that the internal heat of a compost pile is relatively independent of the ambient temperatures as the heat is generated by internal microbiological activity, not outside air temperature.

deposits from the sawdust toilet, which contained raw hardwood sawdust, humanure including all urine, and toilet paper. In addition to this material, kitchen food scraps were added to the pile intermittently throughout the winter, and hay was used to cover the toilet deposits on the pile. Some weeds and leaves were added now and then.

The material was continuously collected from a family of four. Nothing special was done to the pile at any time. No unusual ingredients were added, no compost starters, no water, no animal manures other than human (although a little chicken manure was added to the pile charted on the right, which may explain the higher composting temperatures). No turning was done whatsoever. The compost piles were situated in a three-sided, open-topped wooden

bin on bare soil, outdoors. The only imported materials were raw sawdust, a locally abundant resource, and hay from a neighboring farm (less than two bales were used during the entire winter).

Two thermometers were used to monitor the temperature of this compost, one having an 8" probe, the other having a 20" probe. The outside of the pile (8" depth) shown on the left graph was heated by thermophilic activity before the inside (20" depth). The outside thawed first, so it started to heat first. Soon thereafter, the inside thawed and also heated. By April 8th, the outer part of the pile had reached 50°C (122°F) and the temperature remained at that level or above until April 22nd (a two-week period). The inside of the pile reached 122°F on April 16th, over a week later than the outside, and remained there or above until April 23rd. The pile shown in the right graph was above 122°C for 25 days.

Since 1993, I have monitored my humanure compost temperatures continuously, year round. The compost typically reaches 120 degrees F. (49C), at a depth of 20", in early spring and now stays there all summer and fall. In the winter, the temperature drops, but the compost piles have not frozen since 1997. In fact, the compost thermophiles seem to be adapting to the cold winters of Pennsylvania and it is not uncommon for my compost to read temperatures over 100 degrees F all winter long, even when the ambient air temperature is in the single digits. The maximum temperature I have recorded is about 149 degrees F. (65C), but more typical temperatures range from 110F (44C) to 122F (50C). For some reason, the compost seems to stay around 120F most of the summer months (at a depth of 20").

According to Dr. T. Gibson, Head of the Department of Agricultural Biology at the Edinburgh and East of Scotland College of Agriculture, *"All the evidence shows that a few hours at 120 degrees Fahrenheit would eliminate [pathogenic microorganisms] completely. There should be a wide margin of safety if that temperature were maintained for 24 hours."*<sup>2</sup>

Incidentally, I am writing this paragraph on February 24, 2005. I emptied four 5-gallon humanure compost buckets this morning before I started writing. The outdoor temperature was 22 degrees F. The compost temperature at 20" depth was just over 100 degrees F. I glanced at the clock before I started emptying the compost, then again after I had finished and washed my hands. Exactly fifteen minutes had elapsed. This is a weekly chore and more time consuming in the winter because a gallon jug of water has to be carried out with the compost in order to rinse the buckets (the rain barrel at the

Humanure Hacienda is drained during the winter months and no water is available there). I have never paid much attention to how time-consuming (or not) humanure composting can be, so I was surprised that it took only fifteen minutes to empty four buckets at a leisurely pace during the worst time of year.

I shouldn't be surprised, though, because we've developed an efficient system over the years — we use a four-bucket system because two buckets are easier to carry than one, and four buckets will last approximately one week for a family of four, which means only emptying compost on a weekly basis. In the winter, one gallon of water is required for rinsing purposes for every two compost buckets. That means four people will need 1/2 gallon of water each per week for toilet use, requiring about four minutes per person per week for compost emptying.

Granted, there is additional time required to acquire and stockpile cover materials — a job usually done in the summer or fall (we go through about ten bales of straw or hay each year, plus a pickup truck load of sawdust). A few minutes each week are also needed to refill cover material containers in the toilet room (in our household this is usually a job for the kids). The biggest task is wheelbarrowing the compost to the garden each spring. But then, that's the whole idea — making compost.

#### FECOFRIGGINFOBIA

There seems to be an irrational fear among fecophobes that if you don't die instantly from humanure compost, you'll die a slow, miserable death, or you'll surely cause an epidemic of the plague and everyone within 200 miles of you will drop like flies, or you'll become so infested with parasitic worms that your head will look like spaghetti.

These fears exist perhaps because much of the information in print concerning the recycling of humanure is confusing, erroneous, or incomplete. For example, when researching the literature during the preparation of this book, I found it surprising that almost no mention is ever made of the thermophilic composting of humanure as a viable alternative to other forms of on-site sanitation. When "bucket" systems are mentioned, they are also called "cartage" systems and are universally decried as being the least desirable sanitation alternative.

For example, in *A Guide to the Development of On-Site*

*Sanitation* by Franceys et al., published by the World Health Organization in 1992, “bucket latrines” are described as “*malodorous, creating a fly nuisance, a danger to the health of those who collect or use the nightsoil, and the collection is environmentally and physically undesirable.*” This sentiment is echoed in Rybczynski’s (et al.) World Bank funded work on low-cost sanitation options, where it is stated that “*the limitations of the bucket latrine include the frequent collection visits required to empty the small container of [humanure], as well as the difficulty of restricting the passage of flies and odors from the bucket.*”

I’ve personally used a sawdust toilet for 26 years and it has never caused odor problems, fly problems, health problems, or environmental problems. Quite the contrary, it has actually *enhanced* my health, the health of my family, and the health of my environment by producing healthy, organic food in my garden, and by keeping human waste out of the water table. Nevertheless, Franceys et al. go on to say that “[humanure] collection should never be considered as an option for sanitation improvement programmes, and all existing bucket latrines should be replaced as soon as possible.”

Obviously Franceys et al. are referring to the practice of collecting humanure in buckets without a cover material (which would surely stink to high heaven and attract flies) and without any intention of composting the humanure. Such buckets of feces and urine are presumably dumped raw into the environment. Naturally, such a practice should be strongly discouraged, if not outlawed.

However, rather than forcing people who use such crude waste disposal methods to switch to other more prohibitively costly waste disposal methods, perhaps it would be better to educate those people about *resource recovery*, the *human nutrient cycle* and about *composting*. It would be more constructive to help them acquire adequate and appropriate *cover materials* for their toilets, assist them in constructing *compost bins*, and thereby eliminate waste, pollution, odor, flies and health hazards altogether. I find it inconceivable that intelligent, educated scientists who observe bucket latrines and the odors and flies associated with them do not see that the simple addition of a clean, organic cover material to the system would solve the aforementioned problems, and balance the nitrogen of the humanure with carbon.

Franceys et al. state, however, in their book, that “*apart from storage in double pit latrines, the most appropriate treatment for on-site sanitation is composting.*” I would agree that composting, when done properly, is the most appropriate method of on-site sanitation available to

### THE SAWDUST TOILET ON CAMPING TRIPS

Humanure composters have tricks up their sleeves. Ever go on a week-long camping trip or to a camping music festival and hate using those awful portable chemical toilets that stink? If you have a humanure compost bin at home, simply take two five gallon buckets with you on the trip. Fill one with a cover material, such as sawdust, and put a lid on it. Set it inside the empty bucket and pack it along with your other camping gear. Voila! One portable composting toilet! When you set up your camp, string up a tarp for privacy and set the two containers in the private space. Use the empty container as a toilet, and use the cover material to keep it covered. Place a lid on it when not in use. No standing in line, no odors, no chemicals, no pollution. This toilet will last several days for two people. When you leave the camp, take the "soil nutrients" home with you and add them to your compost pile. You will probably be the only campers there who didn't leave *anything* behind, a little detail that you can be proud of. And the organic material you collected will add another tomato plant or blueberry bush to your garden. You can improve on this system by taking a toilet seat that clamps on a five gallon bucket, or even taking along a home-made toilet box with seat.

### A SIMPLE URINAL

Want to collect urine only? Maybe you want a urinal in a private office, bedroom or shop. Simply fill a five-gallon bucket with rotted sawdust or other suitable material, and put a tight lid on it. A bucket full of sawdust will still have enough air space in it to hold about a week's worth of urine from one adult. Urinate into the bucket, and replace the lid when not in use. For a fancy urinal, place the sawdust bucket in a toilet cabinet with a regular toilet seat. When the bucket is full, deposit it on your compost pile. The sawdust inhibits odors, and balances the nitrogen in the urine. It sure beats the frequent trips to a central toilet room that coffee drinkers are inclined to make, and no "soil nutrients" are going to waste down a drain.

#### READER



#### WHY NOT PLACE THE COMPOST BINS DIRECTLY UNDERNEATH THE TOILET?

The thought of carrying buckets of humanure to a compost bin can deter even the most dedicated recycler. What if you could situate your toilet directly over your compost bins? Here's some reader feedback:

#### FEEDBACK

"I finally write back to you after 2 1/2 years of excitingly successful and inspiring use of humanure methods applied to a 'direct shitter' compost. We indeed built a beautiful humanure receptacle 10 feet long, 4 feet high and 5 feet wide, divided into two chambers. One chamber was used (sawdust after every shit, frequent green grass and regular dry hay applications) from May 1996 until June 1997, then nailed shut. We moved to the second chamber until June 1998 — when with excitement mounting, we unscrewed the boards at the back of the "Temple of Turds" (our local appellation) and sniffed the aroma...of the most gorgeous, chocolate brownie, crumbly compost ever SEEN. Yes, I thrust my hands fully into the heavenly honey pot of sweet soil, which soon thereafter graced the foundations of our new raspberry bed. Needless to say, the resulting berries knew no equal. Humanure and the potential for large-scale . . . even a city size composting collection (apartment building toilets into a central collection dumpster), along with the crimes of the so-called "septic system," has become one of my most favored topics of conversation and promotion. Often through direct exposition at our farm. Many thanks for your noble work of art and contribution to this stinky species of ape." R.T. in CT

**From a Public Radio Commentary**

"People are saying that the Year 2000 computer problem could foul up a lot of stuff we usually depend on, all at once. I thought I'd give this Y2K Practice Day a try. Turn off the heat, lights, water and phones. Just for 24 hours. The day before Practice Day, I complained to Larry, telling him that I was bitterly disappointed not to try out an emergency toilet. This complaining really paid off. Larry, who's also a writer researching Year 2000 emergency preparedness, phoned a man named Joe Jenkins, author of a book called the Humanure Handbook. Joe reassured my husband of the safe, sanitary, and uncomplicated method for composting human waste. His solution is based on 20 years of scholarly study. It turns out that the thermophilic bacteria in human waste, when mixed with organic material like peat moss or sawdust, creates temperatures over 120 degrees Fahrenheit, rapidly killing pathogens just as Mother Nature intended.

We grew bold and daring and decided to use our emergency five gallon bucket with the toilet seat, layering everything with peat moss. Larry spent maybe a half hour building a special compost bin. This was right up his alley, since he already composts all the kitchen scraps, yard, and dog wastes.

Surprisingly, I found myself liking that little toilet. It was comfortable, clean, with no odor, just a slightly earthy smell of peat moss. The soul-searching came when I contemplated going back to the flush toilet.

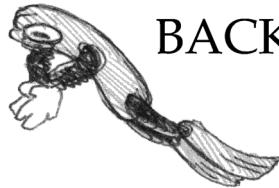
By coincidence, I recently heard a presentation by the director of the local waste treatment facility. He was asked to address the issue of Year 2000 disruptions and explain what preparations were being made. In a matter-of-fact voice, he described what a visitor from another planet would undoubtedly consider a barbaric custom. First, we defecate and urinate in our own clean drinking water. In our town, we have 800 miles of sewers that pipe this effluent to a treatment facility where they remove what are euphemistically called solids. Then they do a bunch more stuff to the water, I forget exactly what. But I do remember that at one point, they dose it with a potent poison — chlorine, of course — and then they do their best to remove the chlorine. When all this is done, the liquid gushes into the Spokane River.

At this meeting was a man named Keith who lives on the shores of Long Lake, down river from us. Keith was quite interested to know what might occur if our sewage treatment process was interrupted. The waste treatment official assured him that all would be well, but I couldn't help reflecting that Keith might end up drinking water that we had been flushing. I like Keith. So I decided to keep on using my camp toilet.

My husband is a passionate organic gardener, at his happiest with a shovel in his hand, and he's already coveting the new compost. He's even wondering if the neighbors might consider making a contribution. I'm just grateful the kids are grown and moved out, because they'd have a thing or two to say."

Judy Laddon in WA (excerpted with permission)

**READERS  
WRITE  
BACK**



humans. I would not agree that double pit storage is more appropriate than thermophilic composting unless it could be proven that human pathogens could be adequately destroyed using such a double pit system, and that such a system would be comfortable and convenient, would produce no unpleasant odor and would not require the segregation of urine from feces. According to Rybczynski, the double pit latrine shows a reduction of *Ascaris* ova of 85% after two months, a statistic which does not impress me. When my compost is finished, I don't want *any* pathogen threat lurking in it.

Ironically, the work of Franceys et al. further illustrates a "decision tree for selection of sanitation" that indicates the use of a "compost latrine" as being one of the least desirable sanitation methods, and one which can only be used if the user is willing to collect urine separately. Unfortunately, contemporary professional literature is rife with this sort of inconsistent, incomplete and incorrect information which would surely lead a reader to believe that composting humanure just isn't worth the trouble.



On the other hand, Hugh Flatt, who, I would guess, is a practitioner and not a scientist, in *Practical Self-Sufficiency* tells of a sawdust toilet system he had used for decades. He lived on a farm for more than 30 years which made use of “bucket lavatories.” The lavatories serviced a number of visitors during the year and often two families in the farmhouse, but they used no chemicals. They used sawdust, which Mr. Flatt described as “absorbent and sweet-smelling.” The deciduous sawdust was added after each use of the toilet, and the toilet was emptied on the compost pile daily. The compost heap was located on a soil base, the deposits were covered each time they were added to the heap, and kitchen refuse was added to the pile (as was straw). The result was “*a fresh-smelling, friable, biologically active compost ready to be spread on the garden.*”<sup>3</sup>

Perhaps the "experts" will one day understand, accept and advocate simple humanure composting techniques such as the sawdust toilet. However, we may have to wait until Composting 101 is taught at universities, which may occur shortly after hell freezes over. In the meantime, those of us who use simple humanure composting methods must view the comments of today's so-called experts with a mixture of amusement and chagrin. Consider, for example, the following comments posted on the internet by another “expert.” A reader posted a query on a compost toilet forum website wondering if anyone had any scientific criticism about the above-mentioned sawdust toilet system. The expert replied that he was about to publish a new book on composting toilets, and he offered the following excerpt:

“Warning: Though powerfully appealing in its logic and simplicity, I'd expect this system to have an especially large spread between its theoretical and its practical effectiveness. If you don't have a consistent track record of maintaining high temperatures in quick compost piles, I'd counsel against using this system. Even among gardeners, only a small minority assemble compost piles which consistently attain the necessary high temperatures . . . Health issues I'd be concerned about are 1) bugs and small critters fleeing the high-temperature areas of the pile and carrying a coat of pathogen laden feces out of the pile with them; 2) large critters (dogs, raccoons, rats . . .) raiding the pile for food and tracking raw waste away; and 3) the inevitable direct exposure from carrying, emptying, and washing buckets.

Some clever and open-minded folk have hit on the inspiration of composting feces . . . by adding them to their compost piles! What a revolutionary concept! . . . Sound too good to be true? Well, in theory it is true, though in practice I believe that few folks would pass

## FREQUENTLY ASKED QUESTIONS ABOUT SAWDUST TOILETS

### **Should a sawdust toilet be inside or outside?**

Inside. It is much more comfortable during cold and wet weather. The contents of an outside toilet will freeze in the winter and will be very difficult to empty into the compost bin. Keep a clean layer of sawdust over the toilet contents at all times and you won't have any odor inside.

### **Can the sawdust toilet receptacle be left for long periods without emptying?**

The toilet can sit for months without emptying. Just keep a clean layer of sawdust or other cover over the contents.

### **How full should the sawdust toilet receptacle be before it's emptied?**

You know it's time to empty the toilet when you have to stand up to take a shit.

### **Should a compost pile be separated from the earth by a waterproof barrier to prevent leaching?**

Put a sheet of plastic under your compost and arrange it to drain into a sunken bucket if leaching is a concern. Any leachate collected can be poured over the compost. Otherwise, use an earth bottom.

### **What sort of seal should I use around the toilet seat lid?**

You don't need a seal around the toilet seat lid. The "seal" is created by the organic material that covers the humanure.

### **Can I use leaves as a cover material in my compost pile?**

Leaves are great. Keep a bale of straw or hay around too, if you can. It will trap more air.

### **What about winter composting? Can I add to a snow-covered compost pile?**

Just deposit on top of the snow. The main problem in the winter is the cover material freezing. So you need to cover your leaves, sawdust, hay, or whatever you use to prevent them from freezing so you can use them all winter long. I just throw a tarp over my outdoor pile of sawdust then cover that with a thick layer of straw, and there always seems to be a section of the sawdust that I can dig out, unfrozen, in the winter.

### **Does a compost bin need to have an open side? Shouldn't a bin be enclosed in an urban situation?**

You don't need an open side. Someone wrote to me from Manhattan who had installed sawdust toilets in a communal home, and he made a four sided bin (one side removable) with a heavy screen top to keep out anything that might want to try to get in (like flies, rats, skunks, snakes or politicians). That seemed like a good idea for a city situation (a screen bottom may be necessary too). I've also had people write to me from other large cities telling me they're now using sawdust toilets in the city, with a backyard compost bin. Wrap your bins in chicken wire if animals are a problem.

### **Where do you keep your sawdust? I can't seem to decide where to store it.**

I have lots of space and I just have a dump truck bring me a load of sawdust every year or two and dump it out by my compost bins. If I didn't have that option I might try using peat moss, which is handily packaged and could be kept indoors, or bag up sawdust in feed sacks (one of my neighbors did this), or use a three-chambered bin and put the sawdust in the center chamber.

### **How do I know the edges of the compost pile will get hot enough to kill all pathogens?**

You will never be absolutely certain that every tiny bit of your compost has been subjected to certain temperatures, no matter what you do. If in doubt, let it age for an additional year, have it tested at a lab, or use the compost on non-food crops.

### **Can I build my compost bin under my house and defecate directly into it?**

Yes, but I have never tried this and can't personally vouch for it.

### **What about meat and dairy products in compost?**

They'll compost. Dig them into the top center of the pile, and keep it all covered with a clean, organic material.

## FREQUENTLY ASKED QUESTIONS ABOUT SAWDUST TOILETS

### **What about building codes, septic permits, and other government regulations?**

Some composters are inclined to believe that government bureaucrats are against composting toilets. This is more paranoia than truth. Alternative solutions are becoming more attractive as the sewage issue continues to get worse. Government agencies are looking for alternative solutions that work, and they are willing to try new things. Their concerns are legitimate, and change comes slowly in government. If you work cooperatively with your local authority, you may both be satisfied in the end.

### **What about flies and rats in the compost?**

Flies should not be a problem if the compost is adequately covered. If you have rats, you may have to envelope your compost bin in wire mesh if you can't get rid of them.

### **Can I use softwood sawdust in my compost?**

Yes. Make sure it's not from "pressure treated" lumber, cedar, or redwood. The sawdust can be moist, but shouldn't be wet.

### **What about using railroad ties to make compost bins?**

The creosote is not good for your compost.

### **What about using dog doo in compost?**

Use a separate compost bin because many dogs are not healthy and pass visible parasites, such as tapeworms, in their stools. Use a cover material, and let the compost age a year or two. Same for cats.

### **What about coffee filters and barbecue ashes?**

Throw coffee filters in your compost. Grounds, too, and even old coffee. Barbecue ashes? Maybe throw them in with the dog doo. Use *that* compost for planting flowers.

### **If I don't want to start using humanure in my compost now, could I do it on short notice in the event of a municipal emergency?**

In the event of a serious municipal emergency, yes, you could immediately begin composting humanure, as long as you had a source of clean cover material (sawdust, leaves, etc.) and a compost bin. Compost works much better when you feed it manure and urine or other nitrogen sources (grass clippings and other greenery, for example), so you may find that humanure greatly improves your compost if you haven't already been adding other animal manures.

### **What is the hottest temperature you have recorded in your compost? Can it get too hot?**

About 65 degrees Celsius (150F). Yes, it can get too hot (see Chapter 3). A cooler pile over a longer period is ideal. It's more likely your compost won't get hot enough. This is often due either to a dry pile (make sure you compost all urine), or to the use of wood chips (do not use wood *chips* — use sawdust).

### **Can you compost humanure with a large family? Would it be too labor intensive?**

For a family of 6-10, depending on body weight, a five gallon compost toilet receptacle would fill daily. A bigger concern would be the supply of organic cover material, which would amount to about five gallons of volume daily also.

### **What about composting on a flood plain? Would a pit latrine work better?**

Don't compost on a flood plain. Don't use a pit latrine.

### **What are some other compost bin designs?**

One design consists of two concentric wire bins with leaves stuffed in between and the humanure going into the center. Another is a bin composed entirely of straw or hay bales. Another design consists of simple wooden pallets arranged on their sides and tied or screwed together to form compost bins.

### **Do you recommend using chlorine bleach as a disinfectant?**

No. It's an environmental contaminant. Try hydrogen peroxide or something more environmentally friendly if you're looking for a germ killer. Or just use soap and water.

all the little hurdles along the way to realizing these benefits. Not because any part of it is so difficult, just that, well, if you never ate sugar and brushed and flossed after every meal, you won't get cavities either.”<sup>4</sup>

Sound a bit cynical? The above comments are entirely lacking in scientific merit and expose an “expert” who has no experience whatsoever about the subject on which he is commenting. It is disheartening that such opinions would actually be published, but not surprising. The writer hits upon certain knee-jerk fears of fecophobes. His comment on bugs and critters fleeing the compost pile coated with pathogen-laden feces is a perfect example. It would presumably be a bad idea to inform this fellow that fecal material is a product of his body, and that if it is laden with pathogens, he’s in very bad shape. Furthermore, there is some fecal material probably inside him at any given moment. Imagine that — pathogen-infested fecal material brimming with disease-causing organisms actually sitting in the man’s bowels. How can he survive?

When one lives with a humanure composting system for an extended period of time, one understands that fecal material comes from one’s body, and exists inside oneself at all times. With such an understanding, it would be hard to be fearful of one’s own humanure, and impossible to see it as a substance brimming with disease organisms, unless, of course, oneself is brimming with disease.

The writer hits upon another irrational fear — large animals, including rats, invading a compost pile and spreading disease all over creation. Compost bins are easily built to be animal-proof. If small animals such as rats are a problem, the compost bin can be lined with chicken wire on all sides and underneath. The compost bins should have side walls such as pallets, straw bales, wood boards, or similar barriers to keep out dogs. A simple piece of wire fencing cut to fit the exposed top of the active compost pile will keep all animals from digging into it while allowing rain water to keep the pile moist.

The writer warns that most gardeners do not have thermophilic compost. Most gardeners also leave critical ingredients out of their compost, thanks to the fear-mongering of the ill-informed. Those ingredients are humanure and urine, which are quite likely to make one’s compost thermophilic. Commercial composting toilets almost never become thermophilic. As we have seen, it is not only the temperature of the compost that destroys pathogens, it is retention time. The sawdust toilet compost pile requires a year’s construction time, and another year’s undisturbed retention time. When a ther-

mophilic phase is added to this process, I would challenge anyone to come up with a more effective, earth-friendly, simpler, low-cost system for pathogen destruction.

Finally, the writer warns of “the inevitable direct exposure from carrying, emptying and washing buckets.” I’m not sure what he’s getting at here, as I have carried, emptied and washed buckets for decades and never had a problem. Wiping one’s butt after defecating requires more “direct exposure” than emptying compost, but I would not discourage people from doing it. It is quite simple to wash one’s hands after defecating and after taking care of the compost, and as you can see, it’s quite easy to get carried away with a frothing-at-the-mouth fecophobic frenzy.

Other recent experts have thrown in their two cents worth on the sawdust toilet. A book on composting toilets mentions the sawdust toilet system.<sup>5</sup> Although the comments are not at all cynical and are meant to be informative, a bit of misinformation manages to come through. For example, the suggestion to use “rubber gloves and perhaps a transparent face mask so you do not get anything splashed on you” when emptying a compost bucket onto a compost pile, caused groans and a lot of eyes to roll when read aloud to seasoned humanure composters. Why not just wear an EPA approved moon suit and carry the compost bucket at the end of a ten-foot pole? How is it that what has just emerged from one’s body can be considered so utterly toxic? Can one not empty a bucket into a compost pile without splashing the contents all over one’s face? More exaggeration and misinformation existed in the book regarding temperature levels and compost bin techniques. One warning to “bury finished compost in a shallow hole or trench around the roots of non-edible plants,” was classic fecophobia. Apparently, humanure compost is to be banned from human food production. The authors recommended that humanure compost be composted *again* in a non-humanure compost pile, or micro-waved for pasteurization, both bizarre suggestions. They add, “Your health agent and your neighbors may not care for this [sawdust toilet composting] method.”

I have to scratch my head and wonder why the “experts” would say this sort of thing. Apparently, the act of *composting* one’s own humanure is so radical and even revolutionary to the people who have spent their lives trying to *dispose* of the substance, that they can’t quite come to grips with the idea. Ironically, a very simple sawdust toilet used by a physician and his family in Oregon is featured and illustrated in the above book. The physician states, “*There is no offend-*



Humanure is added to the author's compost bin, above, observed by Kathleen Meyer, author of *How to Shit in the Woods*. The humanure is deposited into the center of the pile while a thick layer of cover material remains around the outside edges. The deposit is covered immediately afterward. The bucket is then scrubbed and the rinse water poured into the pile. The compost bin is filled for a year, then allowed to age for a year. Below, the aged compost is applied to the spring garden. Photos by author except above, by Jeanine Jenkins.





The human nutrient cycle is completed by returning the household organic material to the soil in order to grow food for people. The author's garden is further amended with grass clipping mulch, a little annual chicken manure and leaf mulch in the fall. It is located immediately adjacent to the home as can be seen in the photo below as well as in the bottom photo on the previous page.



*sive odor. We've never had a complaint from the neighbors.*" Their sawdust toilet system is also illustrated and posted on the internet, where a brief description sums it up: "*This simple composting toilet system is inexpensive both in construction and to operate and, when properly maintained, aesthetic and hygienic. It is a perfect complement to organic gardening. In many ways, it out-performs complicated systems costing hundreds of times as much.*" Often, knowledge derived from real-life experiences can be diametrically opposed to the speculations of "experts." Sawdust toilet users find, through *experience*, that such a simple system can work remarkably well.

What about "health agents"? Health authorities can be misled by misinformation, such as that stated in the preceding accounts. Health authorities, according to my experience, generally know very little, if anything, about thermophilic composting. Many have never even heard of it. The health authorities who have contacted me are very interested in getting more information, and seem very open to the idea of a natural, low-cost, effective, humanure recycling system. They know that human sewage is a dangerous pollutant and a serious environmental problem, and they seem to be surprised and impressed to find out that such sewage can be avoided altogether. Most intelligent people are willing and able to expand their awareness and change their attitudes based upon new information. Therefore, if you are using a sawdust toilet and are having a problem with any authority, please give the authority a copy of this book. I have a standing offer to donate, free of charge, a copy of *The Humanure Handbook* to any permitting agent or health authority, no questions asked, upon anyone's request — just send a name and address to the publisher at the front of this book.

Well-informed health professionals and environmental authorities are aware that "human waste" presents an environmental dilemma that is not going away. The problem, on the contrary, is getting worse. Too much water is being polluted by sewage and septic discharges, and there has to be a constructive alternative. Perhaps that is why, when health authorities learn about the thermophilic composting of humanure, they realize that there may very likely be no better solution to the human waste problem. That may also be why I received a letter from the U.S. Department of Health and Human Services praising this book and wanting to know more about humanure composting, or why the U.S. Environmental Protection Agency wrote to me to commend the *Humanure Handbook* and order copies, or why the Pennsylvania Department of Environmental Protection

nominated *Humanure* for an environmental award in 1998. Fecophobes may think composting humanure is dangerous. I will patiently wait until they come up with a better solution to the problem of “human waste,” but I won’t hold my breath waiting.

## LEGALITIES

This is an interesting topic. The cynic will believe that composting humanure must certainly be illegal. Afterall, humanure is a dangerous pollutant and must immediately be disposed of in a professional and approved manner. Recycling it is foolish and hazardous to your health and to the health of your community and your environment. At least that’s what fecophobes may think. Therefore, recycling humanure cannot be an activity that is within the law, can it? Well, yes actually, the backyard composting of humanure is probably quite within the letter of the laws to which you are subjected.

Waste disposal is regulated, and it should be. Waste disposal is potentially very dangerous to the environment. Sewage disposal and recycling are also regulated, and they should be, too. Sewage includes a host of hazardous substances deposited into a waterborne waste stream. People who compost their humanure are neither disposing of waste, nor producing sewage — they are recycling. Furthermore, regarding the regulating of composting itself, both backyard composting and farm composting are generally exempt from regulations unless the compost is being sold, or unless the farm compost operation is unusually large.

To quote one source, “*The U.S. Department of Environmental Protection (DEP) has established detailed regulations for the production and use of compost created from [organic material]. These regulations exclude compost obtained from backyard composting and normal farming operations. Compost from these activities is exempt from regulation only if it is used on the property where it was composted, as part of the farming operation. Any compost which is sold must meet the requirements of the regulations.*”<sup>6</sup>

Composting toilets are also regulated in some states. However, composting toilets are typically defined as toilets *inside which composting takes place*. A sawdust toilet, by definition, is *not* a composting toilet because no composting occurs in the toilet itself. The composting occurs in the “backyard” and therefore is not regulated by composting *toilet* laws. Portable toilet laws may apply instead, although the backyard compost exemption will probably



allow sawdust toilet users to continue their recycling undisturbed.

A review of composting toilet laws is both interesting and disconcerting. For example, in Maine, it is apparently illegal to put kitchen food scraps down the toilet chute in a commercial composting toilet, even though the food scraps

and toilet materials must go to the exact same place in the composting chamber. Such a regulation makes no sense whatsoever. In Massachusetts, finished compost from composting toilets must be buried under six inches of soil, or hauled away and disposed of by a septage hauler.

Ideally, laws are made to protect society. Laws requiring septic, waste and sewage disposal systems are supposedly designed to protect the environment, the health of the citizens and the water table. This is all to be commended, and conscientiously carried out by those who produce *sewage*, a waste material. If you don't dispose of sewage, you have no need for a sewage disposal system. The number of people who produce backyard compost instead of sewage is so minimal, that few, if any, laws have been enacted to regulate the practice.

If you're concerned about your local laws, go to the library and see what you can find about regulations concerning backyard compost. Or inquire at your county seat or state agency as statutes, ordinances and regulations vary from locality to locality. If you don't want to dispose of your manure but want to compost it instead (which will certainly raise a few eyebrows at the local municipal office), you may have to stand up for your rights.

A reader called from a small state in New England to tell me his story. It seems the man had a sawdust toilet in his house, but the local municipal authorities decided he could only use an "approved" waterless toilet, meaning, in this case, an incinerating toilet. The man did not want an incinerating toilet because the sawdust toilet was working well for him and he liked making and using the compost. So he complained to the authorities, attended township meetings and put up a fuss. To no avail. After months of "fighting city hall," he gave

up and bought a very expensive and “approved” incinerating toilet. When it was delivered to his house, he had the delivery people set it in a back storage room — and that’s where it remained, still in the packing box, never opened. The man continued to use his sawdust toilet for years after that. The authorities knew that he had bought the “approved” toilet, and thereafter left him alone. He never did use it, but the authorities didn’t care. He *bought* the damn thing and had it in his house, and that’s what they wanted. Those local authorities obviously weren’t rocket scientists.

Another interesting story comes from a fellow in Tennessee. It seems that he bought a house which had a rather crude sewage system — the toilet flushed directly into a creek behind the house. The fellow was smart enough to know this was not good, so he installed a sawdust toilet. However, an unfriendly neighbor assumed he was still using the direct waste dump system, and the neighbor reported him to the authorities. But let him tell it in his own words:

Our primitive outhouse employs a rotating 5-gallon bucket sawdust shitter that sits inside a ‘throne.’ Our system is simple & based largely on your book. We transport the poop to a compost pile where we mix the mess with straw & other organic materials. The resident in our cabin before we bought the farm used a flush toilet that sent all sewage directly to a creekbed. An un-informed neighbor complained to the state, assuming that we used the same system. The state people have visited us several times. We were forced to file a \$100 application for a septic system but the experts agree that our hilly, rocky house site is not suitable for a traditional septic system even if we wanted one. They were concerned about our grey water as well as our composting outhouse. My rudimentary understanding of the law is that the state approves several alternative systems that are very complicated and at least as expensive as a traditional septic. The simple sawdust toilet is not included & the state does not seem to want any civilian to actually transport his own shit from the elimination site to a different decomposition site. The bureaucrats tentatively approved an experimental system where our sewage could feed a person-made aquatic wetlands type thingie & they agreed to help us design & implement that system. Currently, we cannot afford to do that on our own & continue to use our sawdust bucket latrine. The officials seem to want to leave us alone as long as our neighbors don’t complain anymore. So, that’s a summary of our situation here in Tennessee. I’ve read most of the state laws on the topic; like most legal texts, they are virtually unreadable. As far as I can tell, our system is not explicitly banned but it is not included in the list of “approved” alternative systems that run the gamut from high-tech, low volume, factory-produced composting gizmos to the old fashioned pit latrine. For a while now, I’ve wanted to write an article on our experience and your book. Unfortunately, grad school in English has seriously slowed down my freelance writing.”

In Pennsylvania, the state legislature has enacted legislation “encouraging the development of resources recovery as a means of managing solid waste, conserving resources, and supplying energy.” Under such legislation the term “disposal” is defined as “*the incineration, dumping, spilling, leaking, or placing of solid waste into or on the land or water in a manner that the solid waste or a constituent of the solid waste enters the environment, is emitted into the air or is discharged to the waters of the Commonwealth.*”<sup>7</sup> Further legislation has been enacted in Pennsylvania stating that “*waste reduction and recycling are preferable to the processing or disposal of municipal waste,*” and further stating “*pollution is the contamination of any air, water, land or other natural resources of this Commonwealth that will create or is likely to create a public nuisance or to render the air, water, land, or other natural resources harmful, detrimental or injurious to public health, safety or welfare. . .*”<sup>8</sup> In view of the fact that the thermophilic composting of humanure involves recovering a resource, requires no disposal of waste, and creates no obvious environmental pollution, it is unlikely that someone who *conscientiously* engages in such an activity would be unduly bothered by anyone. Don’t be surprised if most people find such an activity commendable, because, in fact, it is.

If there aren’t any regulations concerning backyard composting in your area, then be sure that when you’re making your compost, you’re doing a good job of it. It’s not hard to do it right. The most likely problem you could have is an odor problem, and that would simply be due to not keeping your deposits adequately covered with clean, not-too-airy, organic “biofilter” material. If you keep it covered, it does not give off offensive odors. It’s that simple. Perhaps shit stinks so people will be naturally compelled to cover it with something. That makes sense when you think that thermophilic bacteria are already in the feces waiting for the manure to be layered into a compost pile so they can get to work. Sometimes the simple ways of nature are truly profound.

What about flies — could they create a public nuisance or health hazard? I have never had problems with flies on my compost. Of course, a clean cover material is kept over the compost pile at all times.

Concerning flies, F. H. King, who traveled through China, Korea and Japan in the early 1900s when organic material, especially humanure, was the only source of soil fertilizer, stated, “*One fact which we do not fully understand is that, wherever we went, house flies were very few. We never spent a summer with so little annoyance from them*

*as this one in China, Korea and Japan. If the scrupulous husbanding of [organic] refuse so universally practiced in these countries reduces the fly nuisance and this menace to health to the extent which our experience suggests, here is one great gain.” He added, “We have adverted to the very small number of flies observed anywhere in the course of our travel, but its significance we did not realize until near the end of our stay. Indeed, for some reason, flies were more in evidence during the first two days on the steamship out from Yokohama on our return trip to America, than at any time before on our journey.”<sup>9</sup>*

If an entire country the size of the United States, but with twice the population at that time, could recycle all of its organic refuse without the benefit of electricity or automobiles and not have a fly problem, surely we in the United States can recycle a greater portion of our own organic refuse with similar success today.

#### ENVIRONMENTAL POTTY TRAINING 101

Simple, low-tech composting systems not only have a positive impact on the Earth’s ecosystems, but are proven to be sustainable. Westerners may think that any system not requiring technology is too primitive to be worthy of respect. However, when western culture is nothing more than a distant and fading memory in the collective mind of humanity thousands (hundreds?) of years from now, the humans who will have learned how to survive on this planet in the long term will be those who have learned how to live in harmony with it. That will require much more than intelligence or technology — it will require a sensitive understanding of our place as humans in the web of life. That self-realization may be beyond the grasp of our egocentric intellects. Perhaps what is required of us in order to gain such an awareness is a sense of humility, and a renewed respect for that which is simple.

Some would argue that a simple system of humanure composting can also be the most advanced system known to humanity. It may be considered the most advanced because it works well while consuming little, if any, non-renewable resources, producing no pollution and actually creating a resource vital to life.

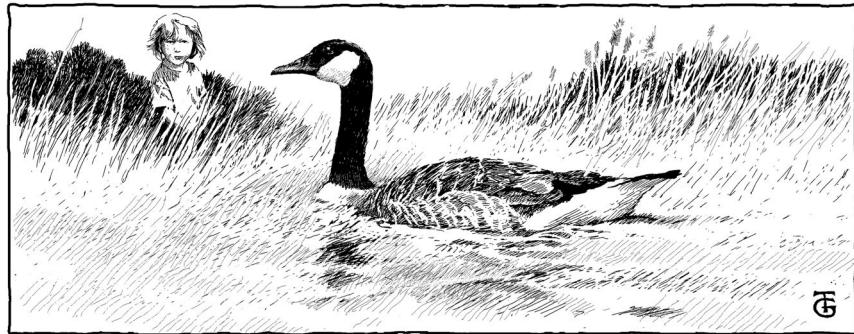
Others may argue that in order for a system to be considered “advanced,” it must display all the gadgets, doodads and technology normally associated with advancement. The argument is that something is advanced if it’s been created by the scientific community, by humans, not by nature. That’s like saying the most advanced method

of drying one's hair is using a nuclear reaction in a nuclear power plant to produce heat in order to convert water to steam. The steam is then used to turn an electric generator in order to produce electricity. The electricity is used to power a plastic hair-drying gun to blow hot air on one's head. That's *technological* advancement. It reflects humanity's *intellectual* progress . . . (which is debatable).

True advancement, others would argue, instead requires the *balanced* development of humanity's intellect with physical and spiritual development. We must link what we know intellectually with the physical effects of our resultant behavior, and with the understanding of ourselves as small, interdependent, interrelated life forms relative to a greater sphere of existence. Otherwise, we create technology that excessively consumes non-renewable resources and creates toxic waste and pollution in order to do a simple task such as hair drying, which is easily done by hand with a towel. If that's advancement, we're in trouble.

Perhaps we're really advancing ourselves when we can function healthfully, peacefully and sustainably without squandering resources and without creating pollution. That's not a matter of mastering the intellect or of mastering the environment with technology, it's a matter of mastering one's self, a much more difficult undertaking, but certainly a worthy goal.

Finally, I don't understand humans. We line up and make a lot of noise about big environmental problems like incinerators, waste dumps, acid rain, global warming and pollution. But we don't understand that when we add up all the tiny environmental problems each of us creates, we end up with those big environmental dilemmas. Humans are content to blame someone else, like government or corporations, for the messes we create, and yet we each continue doing the same things, day in and day out, that have created the problems. Sure, corporations create pollution. If they do, don't buy their products. If you have to buy their products (gasoline for example), keep it to a minimum. Sure, municipal waste incinerators pollute the air. Stop throwing trash away. Minimize your production of waste. Recycle. Buy food in bulk and avoid packaging waste. Simplify. Turn off your TV. Grow your own food. Make compost. Plant a garden. Be part of the solution, not part of the problem. If you don't, who will?



## GRAYWATER SYSTEMS

**T**here are two concepts that sum up this book: 1) one organism's excretions are another organism's food, and 2) there is no waste in nature. We humans need to understand what organisms will consume our excretions if we are to live in greater harmony with the natural world. Our excretions include humanure, urine and *other* organic materials that we discharge into the environment, such as "graywater," which is the water resulting from washing or bathing. Graywater should be distinguished from "blackwater," the water that comes from toilets. Graywater contains recyclable organic materials such as nitrogen, phosphorous and potassium. These materials are pollutants when discarded into the environment. When responsibly recycled, however, they can be beneficial nutrients.

My first exposure to an "alternative" wastewater system occurred on the Yucatan Peninsula of Mexico in 1977. At that time, I was staying in a tent on a primitive, isolated, beach-front property lined with coconut palms and overlooking the turquoise waters and white sands of the Caribbean. My host operated a small restaurant with a rudimentary bathroom containing a toilet, sink and shower, primarily reserved for tourists who paid to use the facilities. The wastewater from this room drained from a pipe, through the wall, and directly into the sandy soil outside, where it ran down an inclined slope out of sight behind the thatched building. I first noticed the drain not because of the odor (there wasn't any that I can remember),

but because of the thick growth of tomato plants that cascaded down the slope below the drain. I asked the owner why he would plant a garden in such an unlikely location, and he replied that he didn't plant it at all — the tomatoes were volunteers; the seeds sprouted from human excretions. He admitted that whenever he needed a tomato for his restaurant, he didn't have to go far to get one. This is not an example of sanitary wastewater recycling, but it is an example of how wastewater can be put to constructive use, even by accident.

From there, I traveled to Guatemala, where I noticed a similar wastewater system, again at a crude restaurant at an isolated location in the Peten jungle. The restaurant's wastewater drain irrigated a small section of the property separate from the camp sites and other human activities, but plainly visible. That section had the most luxurious growth of banana plants I had ever seen. Again, the water proved to be a resource useful in food production, and in this case, the luxurious growth added an aesthetic quality to the property, appearing as a lush tropical garden. The restaurant owner liked to show off his "garden," admitting that it was largely self-planted and self-perpetuating. "That's the value of drain water," he was quick to point out, and its value was immediately apparent to anyone who looked.

All wastewater contains organic materials, such as food remnants and soap. Microorganisms, plants and macroorganisms consume these organic materials and convert them into beneficial nutrients. In a sustainable system, wastewater is made available to natural organisms for their benefit. Recycling organic materials through living organisms naturally purifies water.

In the U.S., the situation is quite different. Household wastewater typically contains all the water from toilet flushings (blackwater) as well as water from sinks, bathtubs and washing machine drains (graywater). To complicate this, many households have in-sink garbage disposals. These contraptions grind up all of the food material that could otherwise be composted, then eject it into the drain system. Government regulators assume the worst-case scenario for household wastewater (lots of toilet flushings, lots of baby diapers in the wash, and lots of garbage in the disposal unit), then they enact regulations to accommodate this scenario. Wastewater is therefore considered a public health hazard which must be quarantined from human contact. Typically, the wastewater is required to go directly into a sewage system, or, in suburban and rural locations, into a septic system.

A septic system generally consists of a concrete box buried underground into which household wastewater is discharged. When the box fills and overflows, the effluent drains into perforated pipes that allow the water to percolate into the soil. The drain field is usually located deep enough in the soil that surface plants cannot access the water supply.

In short, conventional drainage systems isolate wastewater from natural systems, making the organic material in the water unavailable for recycling. At wastewater treatment plants (sewage plants), the organic material in the wastewater is removed using complicated, expensive procedures. Despite the high cost of such separation processes, the organic material removed from the wastewater is often buried in a landfill.

The alternatives should be obvious. Albert Einstein once remarked that the human race will require an entirely new manner of thinking if it is to survive. I am inclined to agree. Our “waste disposal” systems must be rethought. As an alternative to our current throw-away mentality, we can understand that organic material is a resource, rather than a waste, that can be beneficially recycled using natural processes.

In pursuing this alternative, the first step is to *recycle* as much organic material as possible, keeping it *away* from waste disposal systems altogether. We can eliminate all blackwater from our drains by composting all human manure and urine. We can also eliminate almost all other organic material from our drains by composting food scraps. As such, one should avoid using an in-sink garbage disposal. As an indication of how much organic material typically goes down a household drain, consider the words of one composting toilet manufacturer, “*New regulations will soon demand that septic tanks receiving flush toilet and garbage disposal wastes be pumped out and documented by a state certified septic hauler every three years. When toilet and garbage solids and their associated flush water are removed from the septic system and the septic tank is receiving only graywater, the septic tank needs pumping only every twenty years.*”<sup>1</sup> According to the U.S. EPA, household in-sink garbage disposal units contribute 850% more organic matter and 777% more suspended solids to wastewater than do toilets.<sup>2</sup>

The second step is to understand that a drain is not a waste disposal site; it should never be used to dump something to “get rid of it.” This has unfortunately become a bad habit for many Americans. As an example, a friend was helping me process some of my home-made wine. The process created five gallons of spent wine

as a by-product. When I had my back turned, the fellow dumped the liquid down the sink drain. I found the empty bucket and asked what happened to the liquid that had been in it. "I dumped it down the sink," he said. I was speechless. Why would anyone dump five gallons of food-derived liquid down a sink drain? But I could see why. My friend considered a drain to be a waste disposal site, as do most Americans. This was compounded by the fact that he had *no idea* what to do with the liquid otherwise. My household effluent drains directly into a constructed wetland which consists of a graywater pond. Because anything that goes down that drain feeds a natural aquatic system, I am quite particular about what enters the system. I keep all organic material out of the system, except for the small amount that inevitably comes from dishwashing and bathing. All food scraps are composted, as are grease, fats, oils and every other bit of organic food material our household produces. This recycling of organic material allows for a relatively clean graywater that can be easily remediated by a constructed wetland, soilbed or irrigation trench. The thought of dumping something down my drain simply to dispose of it just doesn't fit into my way of thinking. So I instructed my friend to pour any remaining organic liquids onto the compost pile. Which he did. I might add that this was in the middle of January when things were quite frozen, but the compost pile still absorbed the liquid. In fact, that winter was the first one in which the active compost pile did not freeze. Apparently, the 30 gallons of liquid we doused it with kept it active enough to generate heat all winter long.

Step three is to eliminate the use of all toxic chemicals and non-biodegradable soaps in one's household. Chemicals will find their way down the drains and out into the environment as pollutants. The quantity and variety of toxic chemicals routinely dumped down drains in the U.S. is both incredible and disturbing. We can eliminate a lot of our wastewater problems by simply being careful what we add to our water. Many Americans don't realize that most of the chemicals they use in their daily lives and believe to be necessary are not necessary at all. They can simply be eliminated. This is a fact that will not be promoted on TV or by the government (including schools), because the chemical industry might object. I'm quite sure that you, the reader, don't care whether the chemical industry objects or not. Therefore, you willingly make the small effort necessary to find environmentally benign cleaning agents for home use.

Cleaning products that contain boron should not be used with graywater recycling systems because boron is reportedly toxic to most

plants. Liquid detergents are better than powdered detergents because they contribute less salts to the system.<sup>3</sup> Water softeners may not be good for graywater recycling systems because softened water reportedly contains more sodium than unsoftened water, and the sodium may build up in the soil, to its detriment. Chlorine bleach or detergents containing chlorine should not be used, as chlorine is a potent poison. Drain cleaners and products that clean porcelain without scrubbing should not be drained into a graywater recycling system.

Step four is to reduce our water consumption altogether, thereby reducing the amount of water issuing from our drains. This can be aided by collecting and using rainwater, and by recycling graywater through beneficial, natural systems.

The “old school” of wastewater treatment, still embraced by most government regulators and many academics, considers water to be a vehicle for the routine transfer of waste from one place to another. It also considers the accompanying organic material to be of little or no value. The “new school,” on the other hand, sees water as a dwindling, precious resource that should not be polluted with waste; organic materials are seen as resources that should be constructively recycled. My research for this chapter included reviewing hundreds of research papers on alternative wastewater systems. I was amazed at the incredible amount of time and money that has gone into studying how to clean the water we have polluted with human excrement. In all of the research papers, without exception, the idea that we should simply stop defecating in water was never suggested.

## GRAYWATER

It is estimated that 42 to 79% of household graywater comes from the bathtub and shower, 5 to 23% from laundry facilities, 10 to 17% from the kitchen sink or dishwasher, and 5 to 6% from the bathroom sink. By comparison, the flushing of blackwater from toilets constitutes 38 to 45% of all interior water use in the U.S., and is the single largest use of water indoors. On average, a person flushes a toilet six times a day.<sup>4</sup>

Various studies have indicated that the amount of graywater generated per person per day varies from 25 to 45 gallons (96 to 172 liters), or 719 to 1,272 gallons (2,688 to 4,816 liters) per week for a typical family of four.<sup>5</sup> In California, a family of four may produce 1,300 gallons of graywater in a week.<sup>6</sup> This amounts to nearly a 55-gallon drum filled with sink and bath water by every person every

### **FOUR STEPS TOWARD BENEFICIAL GRAYWATER REUSE**

- 1) Keep as much organic material out of the water as possible. Use a compost toilet and have a compost system for food scraps. Never use an in-sink garbage disposal. Compost grease, fats and oils.
- 2) A household drain is not a waste disposal site. Consider the drain as a conduit to the natural world.
- 3) Do not allow any toxic chemicals to enter your drain system. Use biodegradable soaps and environmentally benign cleaning agents.
- 4) Use water sparingly and efficiently. If possible, collect rainwater and/or reuse graywater.

### **APPROXIMATE WATER USE OF STANDARD APPLIANCES**

US top-loading washing machine . . . . .	30 gallons
European front loading washing machine	.10 gallons
Dishwasher . . . . .	3-5 gallons
Low flow shower head, per shower . . . . .	3-7 gallons
Other sink use (shaving, washing, etc.) . . . . .	1-5 gallons

Source: Lindstrom, Carl (1992). *Graywater — Facts About Graywater — What it is, How to Treat it, When and Where to Use it*. [www.greywater.com](http://www.greywater.com)

day, which is then drained into a septic or sewage system. This estimate does not include toilet water. Ironically, the graywater we dispose of can still be useful for such purposes as yard, garden and greenhouse irrigation. Instead, we dump the graywater into sewers and use drinking water to irrigate our lawns.

Reuse of graywater for landscape irrigation can greatly reduce the amount of drinkable water used for irrigation during the summer months when landscape water may constitute 50-80% of the water used at a typical home. Even in an arid region, a three-person household can generate enough graywater to meet all of their irrigation needs.<sup>7</sup> In arid Tucson, Arizona, for example, a typical family of three uses 123,400 gallons of municipal water per year.<sup>8</sup> It is estimated that 31 gallons of graywater can be collected per person, per day, amounting to almost 34,000 gallons of graywater per year for the same family.<sup>9</sup> An experimental home in Tucson, known as Casa del Aqua, reduced its municipal water use by 66% by recycling graywater and collecting rainwater. Graywater recycling there amounted to 28,200 gallons per year, and rainwater collection amounted to 7,400 gallons per year.<sup>10</sup> In effect, recycled graywater constitutes a “new” water supply by allowing water that

was previously wasted to be used beneficially. Water reuse also reduces energy and fossil fuel consumption by requiring less water to be purified and pumped, thereby helping to reduce the production of global warming gases such as carbon dioxide.

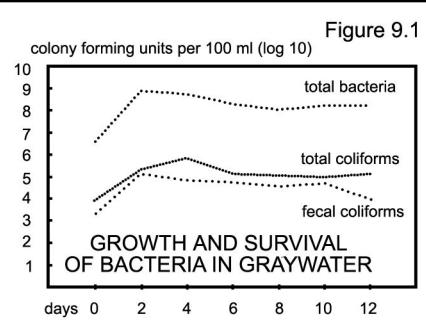
Because graywater can be contaminated with fecal bacteria and chemicals, its reuse is prohibited or severely restricted in many states. Since government regulatory agencies often do not have complete information about graywater recycling, they may assume the worst-case scenario and simply ban its reuse. This is grossly unfair to those who are conscientious about what they put down their drains and who are determined to conserve and recycle water. Graywater experts contend that the health threat from graywater is insignificant. One states, "*I know of no documented instance in which a person in the U.S. became ill from graywater.*"<sup>11</sup> Another adds, "*Note that although graywater has been used in California for about 20 years without permits, there has not been one documented case of disease transmission.*"<sup>12</sup> The health risks from graywater reuse can be reduced first by keeping as much organic material and toxic chemicals out of your drains as possible, and second, by filtering the graywater into a constructed wetland, soilbed or below the surface of the ground so that the graywater does not come into direct human contact, or in contact with the edible portions of fruits and vegetables.

In November of 1994, legislation was passed in California that allowed the use of graywater in single family homes for subsurface landscape irrigation. Many other states do not currently have any legislation regulating graywater. However, many states are now realizing the value of alternative graywater systems and are pursuing research and development of such systems. The U.S. EPA considers the use of wetlands to be an emerging alternative to conventional treatment processes.

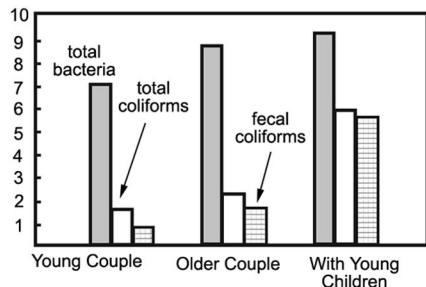
## PATHOGENS

Graywater can contain disease organisms which originate from fecal material or urine entering bath, wash or laundry water. Potential pathogens in fecal material and urine, as well as infective doses, are listed in Chapter 7.

Fecal coliforms are a pollution indicator. Bacteria such as *E. coli* reveal fecal contamination of water and the possible presence of other intestinal disease-causing organisms. A high count is undesirable and indicates a greater chance of human illness resulting from

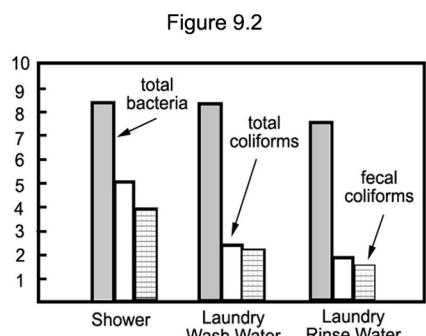


Source: Rose, Joan B. et al. (1991). Microbial Quality and Persistence of Enteric Pathogens in Graywater from Various Household Sources. Water Resources, Vol. 25, No. 1, p. 39, 1991.



**BACTERIA IN GRAYWATER FROM VARIOUS FAMILY GROUPS**

colony forming units per 100 ml (log 10)



**BACTERIA IN GRAYWATER FROM SHOWERS AND LAUNDRY**

colony forming units per 100 ml (log 10)

Source: Rose, Joan B. et al. (1991). Microbial Quality and Persistence of Enteric Pathogens in Graywater from Various Household Sources. Water Resources, Vol. 25, No. 1, pp. 38, 39, 1991.

#### A SHORT GLOSSARY OF SCIENTIFIC WETLAND TERMS

**BOD (BIOLOGICAL OXYGEN DEMAND)** is the amount of oxygen in water that will be consumed by microorganisms in a certain period of time. The more organic nutrients in the water, the greater the BOD, because there will be more microorganisms feeding on the nutrients and consuming oxygen. BOD is measured by obtaining equal volumes of water from a source to be tested. Each specimen is diluted with a known volume of distilled water which has been thoroughly shaken to ensure oxygen saturation. One specimen is measured for dissolved oxygen; the other is set aside in a dark place for five days, then measured. BOD is determined by subtracting the second reading from the first. BOD<sub>5</sub> is a measure of the oxygen depletion after five days. High BOD is an indicator of organic pollution.

**COLIFORM BACTERIA** - Bacteria occurring naturally in the intestines of warm-blooded animals. Most do not cause disease. Drinking water should have less than four coliform bacteria per 100 ml of water. Counts higher than 2,300/100 ml are considered unsafe for swimming, and waters with 10,000/100 ml are unsafe for boating.

**CONSTRUCTED WETLAND** - A human-made complex of saturated substrates (such as gravel), with emergent and submergent plants, animal life and water at or near the surface, which simulates natural wetlands for human use and benefit.

**HYDRIC SOIL** - water-saturated soil

**HYDROPHYTE** - water-loving plant

contact with the graywater. Plant material, soil and food scraps can contribute to the total coliform population, but fecal coliforms indicate that fecal material is also entering the water system. This can come from baby diapers, or just from bathing or showering.

More microorganisms may come from shower and bath graywater than from other graywater sources. Studies have shown that total coliforms and fecal coliforms were approximately ten times greater in bathing water than in laundry water (see Figure 9.2).<sup>13</sup>

One study showed an average of 215 total coliforms per 100 ml and 107 fecal coliforms per 100 ml in laundry water; 1,810 total coliforms and 1,210 fecal coliforms per 100 ml in bath water; and 18,800,000 colony-forming units of total coliforms per 100 ml in graywater containing household garbage (such as when a garbage disposal is used).<sup>14</sup> Obviously, grinding and dumping food waste down a drain greatly increases the bacterial population of the graywater.

Due to the undigested nature of the organic material in graywater, microorganisms can grow and reproduce in the water during storage. The numbers of bacteria can actually increase in graywater within the first 48 hours of storage, then remain stable for about 12 days, after which they slowly decline (see Figure 9.1).<sup>15</sup>

For maximum hygienic safety, follow these simple rules when using a graywater recycling system: don't drink graywater; don't come in physical contact with graywater (and wash promptly if you accidentally do come in contact with it); don't allow graywater to come in contact with edible portions of food crops; don't allow graywater to pool on the surface of the ground; and don't allow graywater to run off your property.

## PRACTICAL GRAYWATER SYSTEMS

The object of recycling graywater is to make the organic nutrients in the water available to plants and microorganisms, preferably on a continuous basis. The organisms will consume the organic material, thereby recycling it through the natural system.

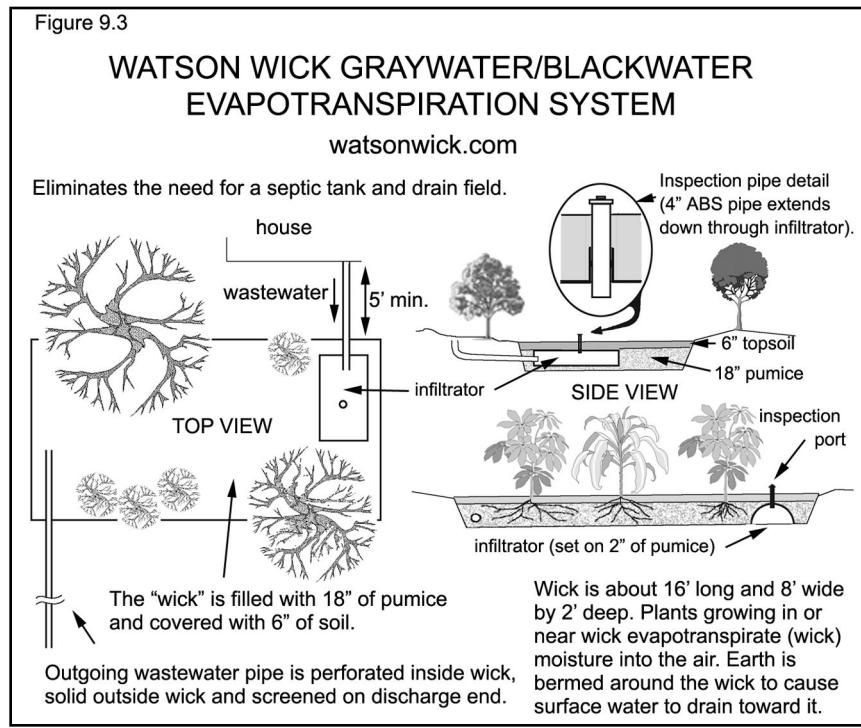
It is estimated that 30 gallons of graywater per person per day will be produced from a water-conservative home. This graywater can be recycled either indoors or outdoors. Inside buildings, graywater can be filtered through deep soil beds, or shallow gravel beds, in a space where plants can be grown, such as in a greenhouse.

Outdoors, in colder climates, graywater can be drained into leaching trenches that are deep enough to resist freezing, but shallow

enough to keep the nutrients within the root zones of surface plants. Freezing can be prevented by applying a mulch over the subsurface leaching trenches. Graywater can also be circulated through constructed wetlands (Figures 9.4, 9.5 and 9.6), mulch basins (Figure 9.8), and soilbeds (Figures 9.8, 9.9, 9.10 and 9.11).

#### EVAPOTRANSPIRATION

Plants can absorb graywater through their roots and then transpire the moisture into the air. A graywater system that relies on such transpiration is called an Evapotranspiration System. Such a system may consist of a tank to settle out the solids, with the effluent draining or being pumped into a shallow sand or gravel bed covered with vegetation. Canna lilies, iris, elephant ears, cattails, ginger lily, and umbrella tree, among others, have been used with these systems. An average two-bedroom house may require an evapotranspiration trench that is three feet wide and 70 feet long. One style of evapotranspiration system consists of a shallow trench lined with clay or other waterproof lining (such as plastic), filled with an inch or two of standard gravel, and six inches of pea gravel. Plants are planted in the



gravel, and no soil is used. A “mother-in-law friendly” evapotranspiration system is the Watson Wick (Figure 9.3).

#### CONSTRUCTED WETLANDS

The system of planting aquatic plants such as reeds or bulrushes in a wet (often gravel) substrate medium for graywater recycling is called a “constructed wetland” or “artificial wetland.” The first artificial wetlands were built in the 1970s. By the early 1990s, there were more than 150 constructed wetlands treating municipal and industrial wastewater in the U.S..

According to the U.S. Environmental Protection Agency, “*Constructed wetlands treatment systems can be established almost anywhere, including on lands with limited alternative uses. This can be done relatively simply where wastewater treatment is the only function sought. They can be built in natural settings, or they may entail extensive earthmoving, construction of impermeable barriers, or building of containment such as tanks or trenches. Wetland vegetation has been established and maintained on substrates ranging from gravel or mine spoils to clay or peat . . . Some systems are set up to recharge at least a portion of the treated wastewater to underlying ground water. Others act as flow-through systems, discharging the final effluent to surface waters. Constructed wetlands have diverse applications and are found across the country and around the world. They can often be an environmentally acceptable, cost-effective treatment option, particularly for small communities.*”<sup>16</sup>

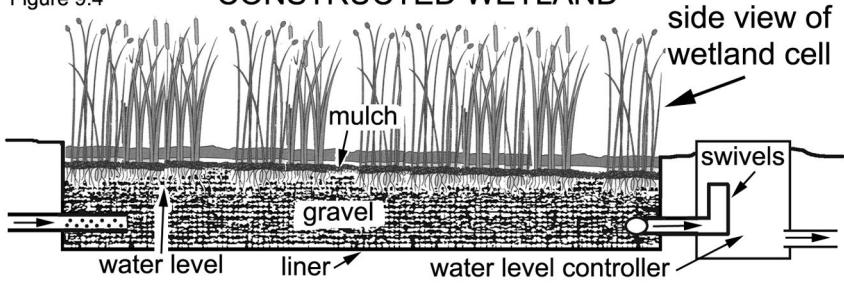
A wetland, by definition, must maintain a level of water near the surface of the ground for a long enough time each year to support the growth of aquatic vegetation. Marshes, bogs, and swamps are examples of naturally occurring wetlands. Constructed wetlands are designed especially for pollution control and exist in locations where natural wetlands do not.

Two types of constructed wetlands are in common use today. One type exposes the water’s surface (Surface Flow Wetland, Figure 9.5), and the other maintains the water surface below the level of the gravel (Subsurface Flow Wetland, Figures 9.4 and 9.6). Some designs combine elements of both. Subsurface flow wetlands are also referred to as Vegetated Submerged Bed, Root Zone Method, Rock Reed Filter, Microbial Rock Filter, Hydrobotanical Method, Soil Filter Trench, Biological-Macrophytic Marsh Bed and Reed Bed Treatment.<sup>17</sup>

Subsurface flow wetlands are considered to be advantageous

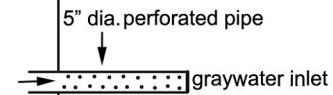
### ASPI SINGLE CELL SUB-SURFACE FLOW CONSTRUCTED WETLAND

Figure 9.4

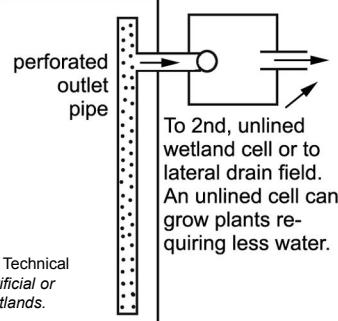


#### top view of wetland cell

The wetland cell is lined with 20 mil plastic, clay, or other water impermeable layer, filled with 12 inches of gravel, and covered with two inches of mulch. Finally, two inches of topsoil are layered on top. Plants are set in the topsoil with their roots in the gravel.



Adapted from ASPI Technical Series TP-30, Artificial or Constructed Wetlands.



#### APPROXIMATE SIZES OF SINGLE CELL CONSTRUCTED WETLANDS WITH LEACH FIELD FOR INDIVIDUAL HOMES

Bedrooms	Size of wetland cell	Length of lateral overflow drain field
1	.120 sq. ft. (4'x30')	100 feet
2	.240 sq. ft. (4'x60')	150 feet
3	.360 sq. ft. (5'x72')	200 feet
4	.480 sq. ft. (6'x80')	300 feet

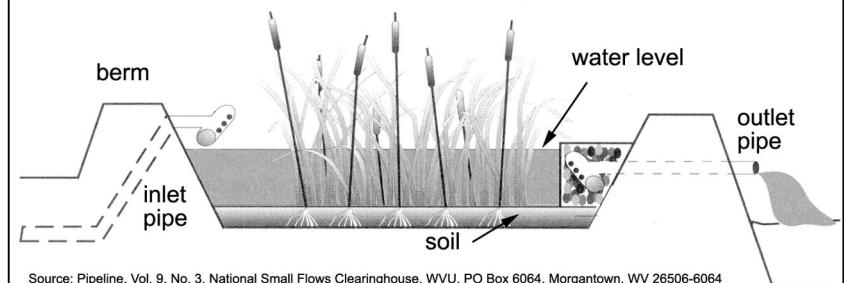
Source: Kentucky State Guidelines as indicated in ASPI Technical Series TP-30, Artificial or Constructed Wetlands.

Liners can be made from polyethylene, butyl rubber, PVC, natural clay, or other waterproof material. Washed 2B gravel or pea gravel, of uniform size, can be used as filler. Sand may be useful as a cushion to protect the liner from the gravel. The soil cover is optional; plants can be planted directly into the gravel. Mulch should be coarse enough to stay on top of the gravel. Connector pipes should be 2" to 4" in diameter. The holes in the perforated inlet and outlet pipes are 1/2" to 3/4" in diameter (depending on diameter of pipe).

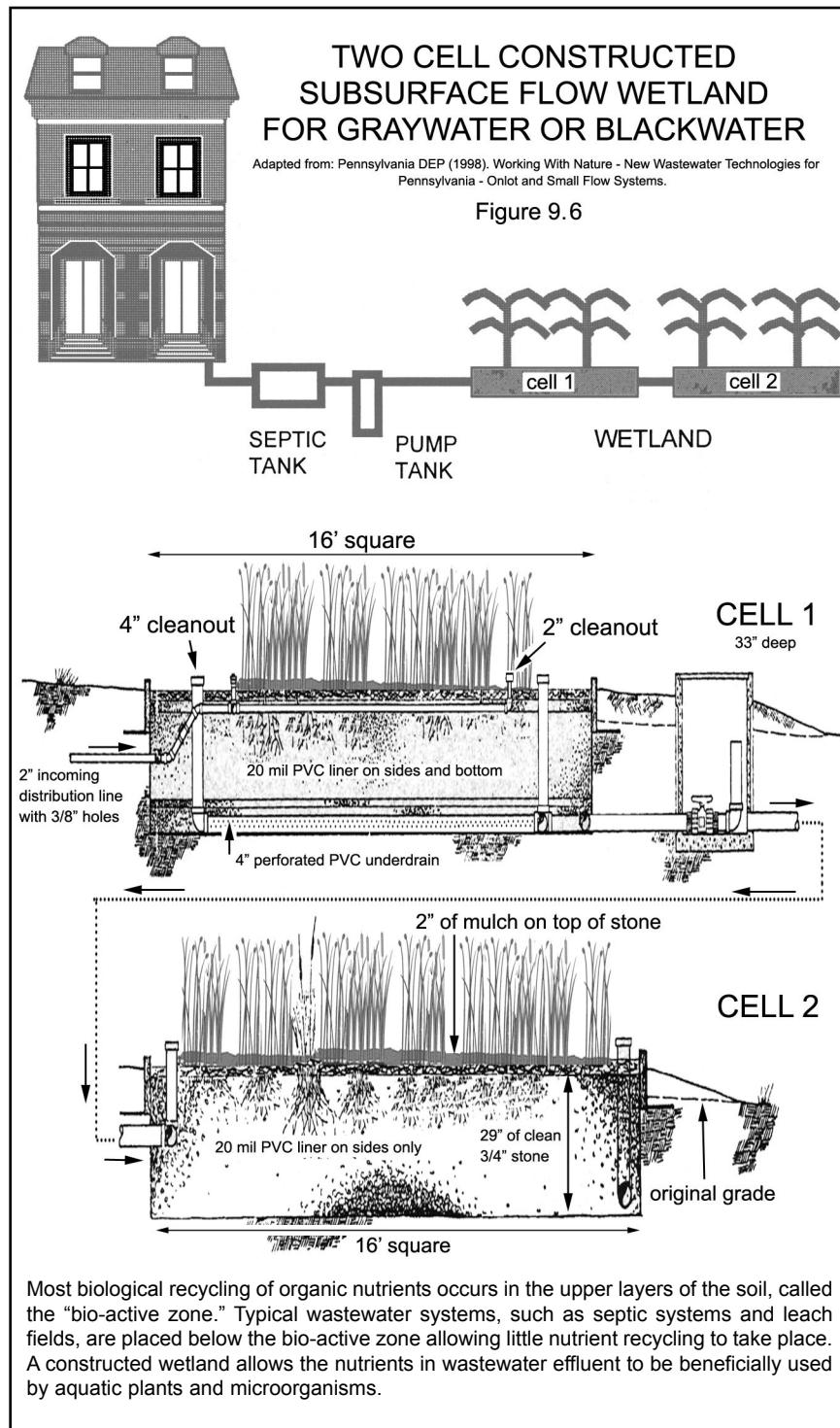
Figure 9.5

### SURFACE FLOW WETLAND

Surface flow wetlands have a typical retention time of 5 to 10 days.



Source: Pipeline, Vol. 9, No. 3. National Small Flows Clearinghouse, WVU, PO Box 6064, Morgantown, WV 26506-6064



Most biological recycling of organic nutrients occurs in the upper layers of the soil, called the "bio-active zone." Typical wastewater systems, such as septic systems and leach fields, are placed below the bio-active zone allowing little nutrient recycling to take place. A constructed wetland allows the nutrients in wastewater effluent to be beneficially used by aquatic plants and microorganisms.

compared to open surface wetlands and are more commonly used for individual households. By keeping the water below the surface of the gravel medium, there is less chance of odors escaping, less human contact, less chance of mosquito breeding, and faster “treatment” of the water due to more of the water being exposed to the microbially populated gravel surfaces and plant roots. The subsurface water is also less inclined to freeze during cold weather.

Constructed wetlands generally consist of one or more lined beds, or cells. The gravel media in the cells should be as uniform in size as possible and should consist of small to medium size gravel or stone, from one foot to three feet in depth. A layer of sand may be used either at the top or the bottom of a gravel medium, or a layer of mulch and topsoil may be applied over the top of the gravel. In some cases, gravel alone will be used with no sand, mulch or topsoil. The sides of the wetlands are bermed to prevent rainwater from flowing into them, and the bottom may be slightly sloped to aid in the flow of graywater through the system. A constructed wetland for a household, once established, requires some maintenance, mainly the annual harvesting of the plants, which can be composted.

In any case, the roots of aquatic plants will spread through the gravel as the plants grow. The most common species of plants used in the wetlands are the cattails, bulrushes, sedges and reeds. Graywater is filtered through the gravel, thereby keeping the growing environment wet, and bits of organic material from the graywater become trapped in the filtering medium. Typical retention times for graywater in a subsurface flow wetland system range from two to six days. During this time, the organic material is broken down and utilized by microorganisms living in the medium and on the roots of the plants. A wide range of organic materials can also be taken up directly by the plants themselves.

Bacteria, both aerobic and anaerobic, are among the most plentiful microorganisms in wetlands and are thought to provide the majority of the wastewater treatment. Microorganisms and plants seem to work together symbiotically in constructed wetlands as the population of microorganisms is much higher in the root areas of the plants than in the gravel alone. Dissolved organic materials are taken up by the roots of the plants, while oxygen and food are supplied to the underwater microorganisms through the same root system.<sup>18</sup>

Aquatic microorganisms have been reported to metabolize a wide range of organic contaminants in wastewater, including benzene, napthalene, toluene, chlorinated aromatics, petroleum hydro-

carbons and pesticides. Aquatic plants can take up and sometimes metabolize water contaminants such as insecticides and benzene. The water hyacinth, for example, can remove phenols, algae, fecal coliforms, suspended particles and heavy metals including lead, mercury, silver, nickel, cobalt and cadmium from contaminated water. In the absence of heavy metals or toxins, water hyacinths can be harvested as a high-protein livestock feed. They can also be harvested as a feedstock for methane production. Reed-based wetlands can remove a wide range of toxic organic pollutants.<sup>19</sup> Duckweeds also remove organic and inorganic contaminants from water, especially nitrogen and phosphorous.<sup>20</sup>

When the outdoor air temperature drops below a certain point during the winter months in cold climates, wetland plants will die and microbial activity will drop off. Therefore, constructed wetlands will not provide the same level of water treatment year round. Artificial wetlands systems constitute a relatively new approach to water purification, and the effects of variables such as temperature fluctuations are not completely understood. Nevertheless, wetlands are reported to perform many treatment functions efficiently in winter. One source reports that the removal rates of many contaminants are unaffected by water temperature, adding, "*The first two years of operation of a system in Norway showed a winter performance almost at the same level as the summer performance.*" Some techniques have been developed to insulate wetland systems during the colder months. For example, in Canada, water levels in wetlands were raised during freezing periods, then lowered after a layer of ice had formed. The cattails held the ice in place, creating an air space over the water. Snow collected on top of the ice, further insulating the water underneath.<sup>21</sup>

It is estimated that one cubic foot of artificial wetland is required for every gallon per day of graywater produced. For an average single bedroom house, this amounts to about a 120 square foot system, one foot deep. Some constructed wetland situations may not have enough drainage water from a residence to keep the system wet enough. In this case, extra water may be added from rain water collection or other sources.

## WETLAND PLANTS

Aquatic plants used in constructed wetland systems can be divided into two general groups: microscopic and macroscopic. Most

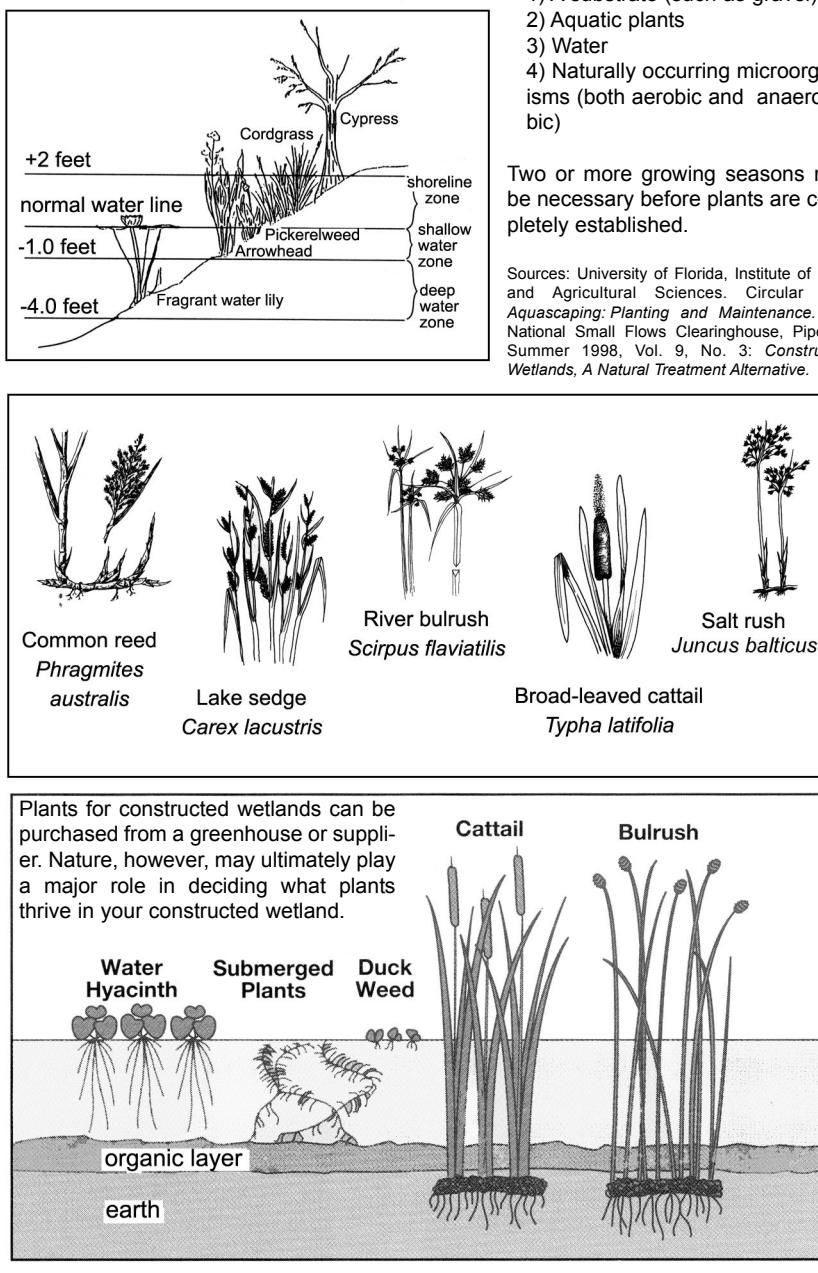
Figure 9.7: AQUATIC PLANTS

A CONSTRUCTED WETLAND  
REQUIRES FOUR COMPONENTS  
FOR FUNCTIONAL SUCCESS

- 1) A substrate (such as gravel)
- 2) Aquatic plants
- 3) Water
- 4) Naturally occurring microorganisms (both aerobic and anaerobic)

Two or more growing seasons may be necessary before plants are completely established.

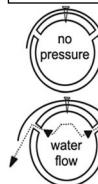
Sources: University of Florida, Institute of Food and Agricultural Sciences. Circular 912, *Aquascaping: Planting and Maintenance*, and National Small Flows Clearinghouse, Pipeline, Summer 1998, Vol. 9, No. 3: *Constructed Wetlands, A Natural Treatment Alternative*.



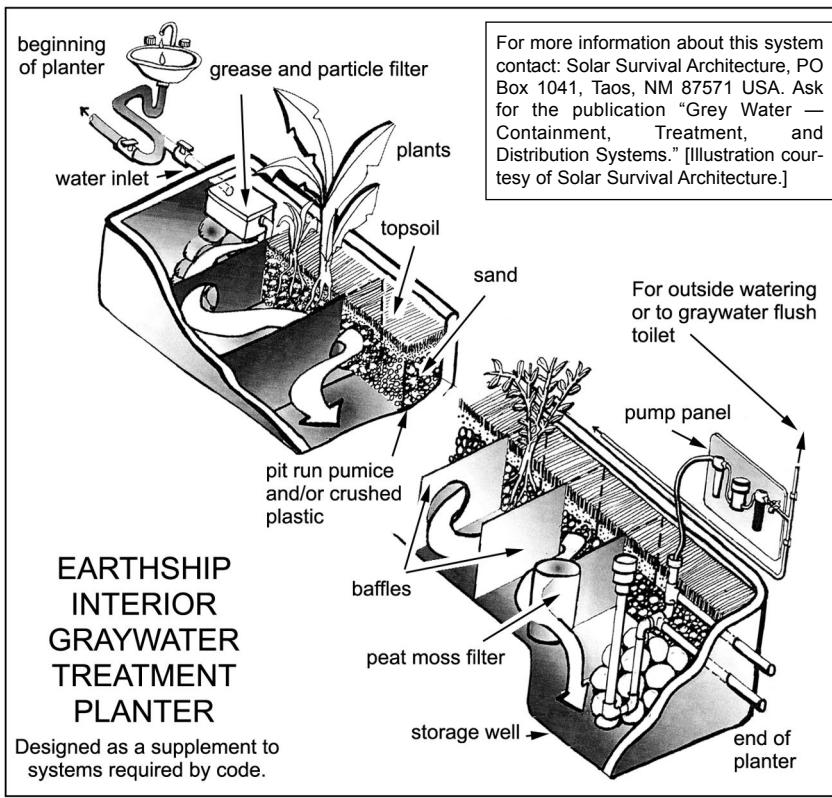
**FIGURE 9.8 SIMPLE GRAYWATER SYSTEM:  
SHALLOW IRRIGATION TO MULCH BASINS**



A 55 gallon drum is shown above collecting water from a washing machine or sink drains. The drum may be located in a basement for year-round use and regularly pumped to the outdoor mulch basins around the trees. The hose is perforated only around the trees, where it is buried in a shallow trench under a heavy mulch. Entire length of hose may be buried for frost protection.

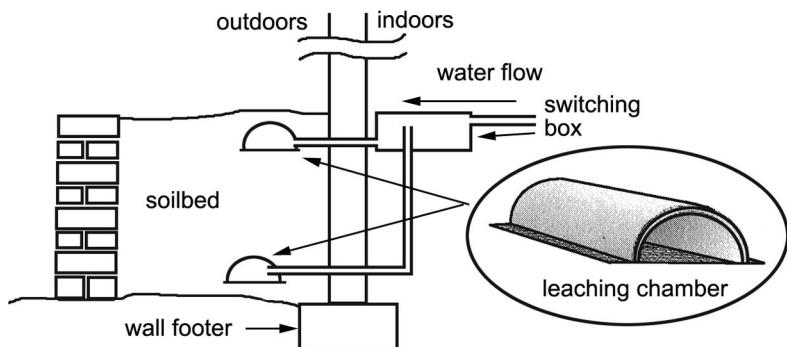
 Acid loving plants such as rhododendron, azalea, foxglove, hydrangea, fern, gardeinia, primrose, begonia, hibiscus, violet, impatiens, and others, should not be used in graywater irrigation systems.

 When water under pressure is used for subsurface irrigation, a sleeve system over the irrigation hose, shown at left, will prevent erosion of the soil around the hose area. The sleeve will also prevent clogging of the irrigation hose by insects and roots. For more information contact Carl Lindstrom at [www.greywater.com](http://www.greywater.com).



## OUTDOOR SOILBED GRAVITY WATERLINE SWITCH For Frozen Conditions

Figure 9.9

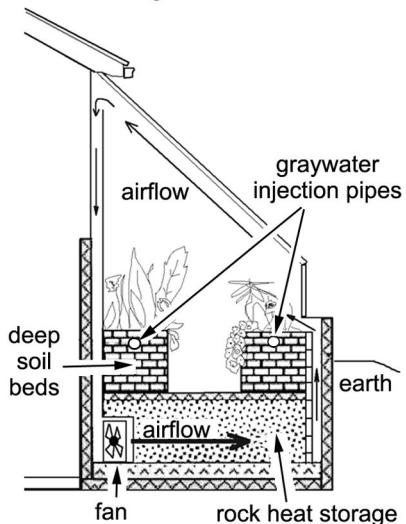


A 6" PVC pipe, cut in half lengthwise and set on plastic netting to keep the pipe from sinking into the soil, creates a handy leaching chamber in soilbeds. When the top leaching chamber freezes, water automatically switches into the lower leaching chamber.

Source: Carl Lindstrom, [www.greywater.com](http://www.greywater.com)

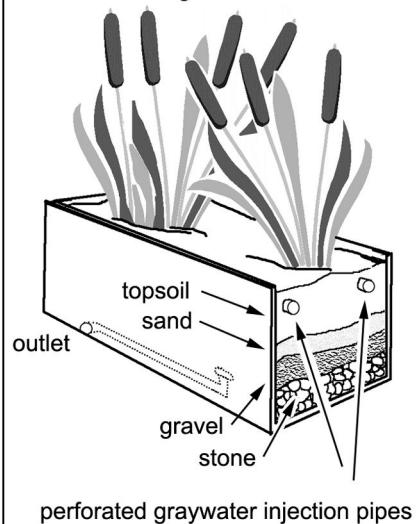
### ATTACHED GREENHOUSE WITH GRAYWATER FILTERING SOILBEDS

Figure 9.10



### SIMPLE SOILBOX GRAYWATER FILTER SYSTEM

Figure 9.11



of the microscopic plants are algae, which can be either single cell (such as *Chlorella* or *Euglena*) or filamentous (such as *Spirulina* or *Spyrogyra*).

Macroscopic (larger) plants can grow under water (submergent) or above water (emergent). Some grow partially submerged and some partially emerged. Some examples of macroscopic aquatic plants are reeds, bulrushes, water hyacinths and duckweeds (see Figure 9.7). Submerged plants can remove nutrients from wastewater, but are best suited in water where there is plenty of oxygen. Water with a high level of organic material tends to be low in oxygen due to extensive microbial activity.

Examples of floating plants are duckweeds and water hyacinths. Duckweeds can absorb large quantities of nutrients. Small ponds that are overloaded with nutrients such as farm fertilizer runoff can often be seen choked with duckweed, appearing as a green carpet on the pond's surface. In a two and a half acre pond, duckweed can absorb the nitrogen, phosphorous and potassium from the excretions of 207 dairy cows. The duckweed can eventually be harvested, dried, and fed back to the livestock as a protein-rich feed. Livestock can even eat the plants directly from a water trough.<sup>22</sup>

Algae work in partnership with bacteria in aquatic systems. Bacteria break down complex nitrogen compounds and make the nitrogen available to algae. Bacteria also produce carbon dioxide which is utilized by the algae.<sup>23</sup>

#### SOILBOXES OR SOILBEDS

A soilbox is a box designed to allow graywater to filter through it while plants grow on top of it (Figure 9.11). Such boxes have been in use since the 1970s. Since the box must be well-drained, it is first layered with rocks, pea gravel, or other drainage material. This is covered with screening, then a layer of coarse sand is added, followed by finer sand; two feet of top soil is added to finish it off. Soilboxes can be located indoors or outdoors, either in a greenhouse, or as part of a raised-bed garden system.<sup>24</sup>

Soilboxes located in indoor greenhouses are illustrated in Figures 9.8 and 9.10. An outdoor soilbed is illustrated in Figure 9.9.

## PEEPERS

An acid spring choked with long, slimy, green algae flows past my house from an abandoned surface coal mine. I introduced baby ducks to the algae-choked water, and quite by accident, I found that the algae disappeared as long as I had ducks swimming in the water. Whether the ducks were eating the algae or just breaking it up paddling their feet, I don't know. In any case, the water changed from ugly to beautiful, almost overnight, by the simple addition of another lifeform to the wetland system. This indicated to me that profound changes could occur in ecological systems with proper — even accidental — management. Unfortunately, constructed wetland systems are still new and there isn't a whole lot of concrete information about them that is applicable to single family dwellings. Therefore, I was forced, as usual, to engage in experimentation.

I built a clay-lined pond near my house about the size of a large swimming pool, then diverted some of the acid mine water to fill the pond. I directed my graywater into this "modified lagoon" wastewater system via a six inch diameter drain pipe with an outlet discharging the graywater below the surface of the pond water. I installed a large drainpipe assuming it would act as a pre-digestion chamber where organic material could collect and break down by anaerobic bacteria en route to the lagoon, like a mini septic tank. I add septic tank bacteria to the system annually by dumping it down the household drains.

Bear in mind that we use a compost toilet and we compost all other organic material. What goes down the household drains is bath water, sink water and laundry water. We do use biodegradable soaps, but do not use an in-sink garbage disposal. Scientific research shows that such *source-separated graywater* has the same or better quality than municipal wastewater effluent *after purification*. In other words, source separated graywater is arguably environmentally cleaner than what's discharged from wastewater treatment plants.<sup>25</sup>

I assumed that the small amount of organic matter that entered the pond from the graywater drain would be consumed by the organisms in the water, thereby helping to biologically remediate the extensively damaged acid mine water. The organic material settles into the bottom of the pond, which is about five feet at the deepest point, thereby being retained in the constructed system indefinitely. I also lined the bottom of the pond with limestone to help neutralize the incoming acid mine water.

The ducks, of course, loved the new pond. They still spend countless hours poking their heads under the water, searching the pond bottom for things to eat. Our house is located between our garden and the pond, and the water is clearly visible from the kitchen sink, as well as from the dining room on the east side of the house, while the nearby garden is visible from the west windows. Shortly after we built the pond, my family was working in our garden. Soon we heard the loud honking of Canada geese in the sky overhead, and watched as a mating pair swooped down through the trees and landed on our new, tiny pond. This was quite exciting, as we realized that we now had a place for wild waterfowl, a bonus we hadn't really anticipated. We continued working in the garden, and were quite surprised to see the geese leave the pond and walk past our house toward the garden where we were busy digging. We continued to work, and they continued to walk toward us, eventually walking right past us through the yard and on to the far end of the garden. When they reached the orchard, they turned around and marched right past us again, making their way back to the pond. To us, this was an initiation for our new pond, a way that nature was telling us we had contributed something positive to the environment.

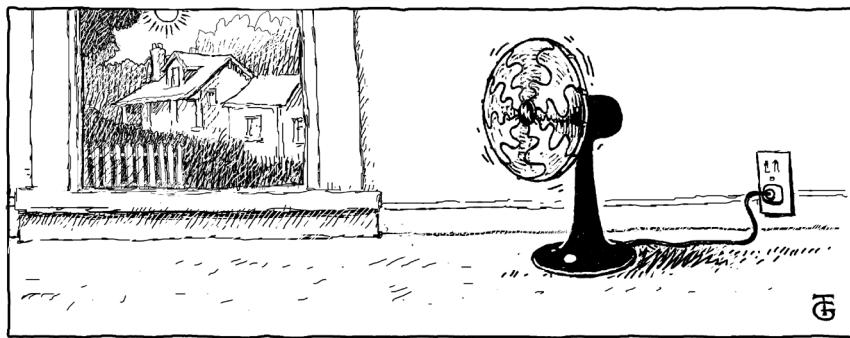
Of course, it didn't end with the two Canada geese. Soon, a Great Blue Heron landed in the pond, wading around its shallow edges on stilt-like legs. It was spotted by one of the children during breakfast, a mere fifty feet from the dining room window. Then, a pair of colorful wood ducks spent an afternoon playing in the water. This was when I noticed that wood ducks can perch on a tree branch like a songbird. Later, I counted 40 Canada geese on the little pond. They covered its surface like a feathery carpet, only to suddenly fly off in a great rush of wings.

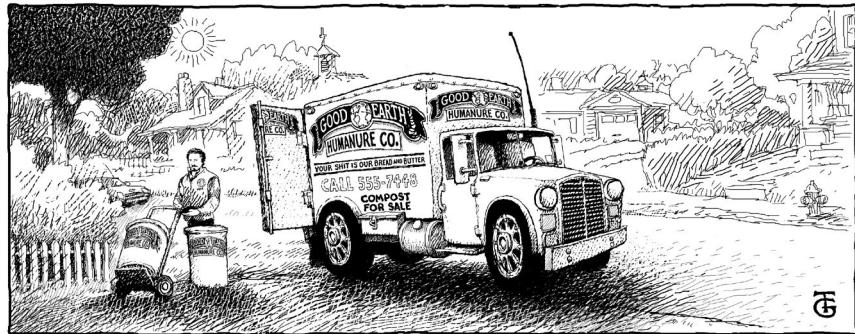
We still raise a few ducks for algae control, for eggs and occasionally for meat. At one point we raised some Mallard ducks, only to find that this wild strain will fly away when they reach maturity. One of the female Mallards became injured somehow, and developed a limp. She was certainly a "lame duck," but the children liked her and took care of her. Then one day she completely disappeared. We thought a predator had killed the defenseless bird and we never expected to see her again. To the children's delight, the following spring a pair of wild Mallard ducks landed on our little pond. We watched them swim around for quite some time, until the female came out of the water and walked toward us. Or, I should say, "limped" toward us. Our lame Mallard duck had flown away for the

winter only to come back in the spring with a handsome boyfriend! Our graywater pond was the point of reference for her migration.

My youngest daughter was given a Canada goose to raise. The tiny gosling couldn't have been more than a day or two old when it was discovered by one of the neighbors wandering lost along a roadside. Phoebe named the goose "Peepers," and everywhere Phoebe went, Peepers followed. The two of them spent many a day at the graywater pond — Peepers splashed around in the water while Phoebe sat on the shore watching. Soon Peepers was a full grown goose and everywhere Peepers went, large piles of goose droppings followed. The goose doo situation became so intolerable to Dad that he renamed the goose "Poopers." One day, when no one else was home, Poopers and Dad took a little trip to a distant lake. Only Dad returned. Phoebe was heartbroken.

The following spring, a pair of honking Canada geese once again flew overhead. But this time, only the female landed in our little pond. Phoebe went running to the pond when she heard that familiar honking, yelling "Peepers! Peepers!" Peepers had come back to say hello to Phoebe! How did I know it was Peepers? I didn't. But somehow, Phoebe did. She stood on the pond bank for quite some time talking to the majestic goose; and the goose, standing on the bank beside her, talked back to her. They carried on a conversation that is rarely witnessed. Finally, Peepers flew off, and this time, Phoebe was happy.





## THE END IS NEAR

Ladies and gentlemen, allow me to introduce you to a new and revolutionary literary device known as the *self-interview!* (Applause heard in background. Someone whoops.) Today I'll be interviewing myself. In fact, here I am now. (Myself walks in.)

*M: Good morning, sir. Haven't I seen you somewhere before?*

*Myself:* Cut the crap. It's too early in the morning for this. You see me every time you look in the mirror, which isn't very often, thank God. What, for crying out loud, would possess you to interview yourself, anyway?

*M: If I don't, who will?*

*MS:* You do have a point there. In fact, that may be an issue worthy of contemplation.

*M: Well, let's not get off the track. The topic of discussion today is a substance near and dear to us all. Shall we step right into it?*

*MS:* What the hell are you talking about?

*M: I'll give you a hint. It often can be seen with corn or peanuts on its back.*

*MS:* Elephants?

*M: Close, but no cigar. Actually, cigar would have been a better guess. We're going to talk about humanure.*

*MS:* You dragged me out of bed and forced me to sit here in front of all these people to talk about CRAP?!

*M: You wrote a book on it, didn't you?*

*MS:* So what? OK, OK. Let's get on with it. I've had enough of

your theatrics.

*M: Well, first off, do you expect anyone to take the Humanure Handbook seriously?*

**MS:** Why wouldn't they?

*M: Because nobody gives a damn about humanure. The last thing anyone wants to think about is a turd, especially their own. Don't you think that by bringing the subject to the fore you're risking something?*

**MS:** You mean like mass constipation? Not quite. I'm not going to put any toilet bowl manufacturers out of business. I'd estimate that one in a million people have any interest at all in the topic of resource recovery in relation to human excrement. Nobody thinks of human manure as a resource; the concept is just too bizarre.

*M: Then what's the point?*

**MS:** The point is that long-standing cultural prejudices and phobias need to be challenged once in a while by somebody, anybody, or they'll never change. Fecophobia is a deeply rooted fear in the American, and perhaps even *human*, psyche. But you can't run from what scares you. It just pops up somewhere else where you least expect it. We've adopted the policy of defecating in our drinking water and then piping it off somewhere to let someone else deal with it. So now we're finding our drinking water sources dwindling and becoming increasingly contaminated. What goes around comes around.

*M: Oh, come on. I drink water every day and it's never contaminated. We Americans probably have the most abundant supply of safe drinking water of any country on the planet.*

**MS:** Yes and no. True, your water may not suffer from fecal contamination, meaning intestinal bacteria in water. But how much chlorine do you drink instead? Then there's water pollution from sewage in general, such as beach pollution. But I don't want to get into all this again. I've already discussed human waste pollution in Chapter Two.

*M: Then you'll admit that American drinking water supplies are pretty safe?*

**MS:** From disease-causing microorganisms, generally yes, they are. Even though we defecate in our water, we go to great lengths and expense to clean the pollutants out of it. The chemical additives in our water, such as chlorine, on the other hand, are not good to drink. And let's not forget that drinking-water supplies are dwindling all over the world, water tables are sinking, and water consumption is on the increase with no end in sight. That seems to be a good reason not to pollute water with our daily bowel movements. Yet, that's only *half*

the equation.

*M: What do you mean?*

MS: Well, we're still throwing away the agricultural resources that humanure could be providing us. We're not maintaining an intact human nutrient cycle. By piping sewage into the sea, we're essentially dumping grain into the sea. By burying sludge, we're burying a source of food. That's a cultural practice that should be challenged. It's a practice that's not going to change overnight, but will change incrementally if we begin acknowledging it now.

*M: So what're you saying? You think everybody should shit in a five-gallon bucket?*

MS: God forbid. Then you would see mass constipation!

*M: Well then, I don't understand. Where do we go from here?*

MS: I'm not suggesting we have a mass cultural change in toilet habits. I'm suggesting that, for starters, we need to change the way we understand our habits. Most people have never heard of such a thing as a nutrient cycle. Many people don't even know about compost. Recycling humanure is just not something people think about. I'm simply suggesting that we begin considering new approaches to the age-old problem of what to do with human excrement. We also need to start thinking a bit more about how we live on this planet, because our survival as a species depends on our relationship with the Earth.

*M: That's a beginning, but that's probably all we'll ever see in our lifetime, don't you think? Some people, like you for example, will think about these things, maybe write about them, maybe even give them some lip service. Most people, on the other hand, would rather have a bag of cheese puffs in one hand, a beer in the other, and a TV in front of them.*

MS: Don't be so sure about that. Things are changing. There are more than a few people who will turn off their TVs, pick the orange crumbs out of their teeth, and get busy making the world a better place. I predict, for example, that composting toilets and toilet systems will continue to be designed and redesigned in our lifetimes. Eventually, entire housing developments or entire communities will utilize composting toilet systems. Some municipalities will eventually install composting toilets in all new homes.

*M: You think so? What would that be like?*

MS: Well, each home would have a removable container made of recycled plastic that would act as both a toilet receptacle and a garbage disposal.

*M: How big a container?*

MS: You'd need about five gallons of capacity per person per week. A container the size of a 50-gallon drum would be full in about

two weeks for an average family. Every household would deposit all of its organic material except graywater into this receptacle, including maybe some grass clippings and yard leaves. The municipality could provide a cover material for odor prevention, consisting of ground leaves, rotted sawdust, or ground newsprint, neatly packaged for each household and possibly dispensed automatically into the toilet after each use. *This would eliminate the production of all organic garbage and all sewage*, as it would all be collected without water and composted at a municipal compost yard.

*M: Who'd collect it?*

MS: Once every couple of weeks or so, your municipality or a business under contract with your municipality would take the compost receptacle from your house. A new compost receptacle would then replace the old. This is already being done in the entire province of Nova Scotia, Canada, and in areas of Europe where organic kitchen materials are collected and composted.

When toilet material is added to the collection system, your manure, urine and garbage, mixed together with ground leaves and other organic refuse or crop residues, would be collected regularly, just like your garbage is collected now. Except the destination would not be a landfill, it'd be the compost yard where the organic material would be converted, through thermophilic composting, into an agricultural resource and sold to farmers, gardeners, and landscapers who'd use it to grow things. The natural cycle would be complete, immense amounts of landfill space would be saved, a valuable resource would be recovered, pollution would be drastically reduced, if not prevented, and soil fertility would be enhanced. So would our long-term survival as human beings on this planet.

*M: I don't know . . . how long before people will be ready for that?*

MS: In Japan today, a similar system is in use, except that rather than removing the container and replacing it with a clean one, the truck that comes for the humanure sucks it out of a holding tank. Sort of like a truck sucking the contents out of a septic tank.

Such a truck system involves a capital outlay about a third of that for sewers. One study which compares the cost between manual humanure removal and waterborne sewage in Taiwan estimates manual collection costs to be less than one-fifth the cost of waterborne sewage treated by oxidation ponds. That takes into account the pasteurization of the humanure, as well as the market value of the resultant compost.<sup>1</sup>

*M: But that's in the Far East. We don't do stuff like that in America.*

MS: One of the most progressive large scale examples I have

seen is in Nova Scotia, Canada. On November 30, 1998, Nova Scotia banned all organic material from entering its landfills. The Province provides free receptacles for every household to deposit their food scraps into. So when a banana peel or burnt pop-tart gets pitched into the trash, it goes into the *green cart* along with egg shells, coffee grounds, and even cereal boxes, waxed paper and file folders. Then, every two weeks, a truck comes around, just like the standard garbage trucks we're used to seeing, and picks up the organic material. From there, it goes to one of many central composting yards, where the material gets run through a grinder and shoved into a giant composting bin. Within 24 to 48 hours, the thermophilic microorganisms in the garbage have raised the temperature of the organic mass to 60-70°C (140-158°F). And it's a totally natural process.

The Netherlands was one of the first countries to mandate large scale source separation of organic material for composting, having done so since 1994; in at least five European countries, such separation is common.<sup>2</sup> Since 1993, in Germany, for example, discarded waste material must contain less than 5% organic matter, otherwise the material has to be recycled, mainly by composting.<sup>3</sup> In England and Wales, a target has been set to compost a million tonnes of organic household material by the year 2000.<sup>4</sup>

*M: But those are not toilets.*

MS: Can't you see? This is only one small step away from collecting toilet materials and composting them, too. Toilets will be redesigned as *collection* devices, not *disposal* devices. We've developed the art, science and technology of composting enough to be able to constructively recycle our own excrement on a large scale.

*M: So why don't we?*

MS: Because humanure doesn't exist, as far as most compost professionals are concerned. It's not even on the radar screen. Human manure is seen as human *waste*, something to be disposed of, not recycled. When I was visiting composting operations in Nova Scotia, one compost educator told me there were 275,000 metric tonnes of animal manures produced annually in his county suitable for composting. He did not include human manure in his assessment. As far as he was concerned, humans are not animals and they don't produce manure.

To give you an example of how clueless Americans are about composting humanure, let me tell you about some missionaries in Central America.

*M: Missionaries?*

MS: That's right. A group of missionaries was visiting an

indigenous group in El Salvador and they were appalled by the lack of sanitation. There were no flush toilets anywhere. The available toilet facilities were crude, smelly, fly-infested pit latrines. When the group returned to the United States, they were very concerned about the toilet problem they had seen and decided they should help. But they didn't know what to do. So they shipped a dozen portable toilets down there, at great expense.

*M: Portable toilets?*

MS: Yeah, you know, those big, plastic outhouses you see at rest stops along the highways, at construction sites and festivals. The ones that smell bad, and are filled with a blue liquid choked with floating turds and toilet paper.

*M: Oh yeah.*

MS: Well, the village in El Salvador got the portable toilets and the people there set them up. They even used them — until they filled up. The following year, the missionaries visited the village again to see how their new toilets were working.

*M: And?*

MS: And nothing. The toilets had filled up and the villagers stopped using them. They went back to their pit latrines. They had a dozen portable toilets sitting there filled to the brim with urine and crap, stinking to high heaven, and a fly heaven at that. The missionaries hadn't thought about what to do with the toilets when they were full. In the U.S., they're pumped out and the contents are taken to a sewage plant. In El Salvador, they were simply abandoned.

*M: So what's your point?*

MS: The point is that we don't have a clue about constructively recycling humanure. Most people in the U.S. have never even had to think about it, let alone do it. If the missionaries had known about composting, they may have been able to help the destitute people in Central America in a meaningful and sustainable way. But they had no idea that human manure is as recyclable as cow manure.

*M: Let me get this straight. Now you're saying that humans are the same as cows?*

MS: Well, all animals defecate. Many westerners simply won't admit it. But we're starting to. We Americans have a long way to go. The biggest obstacle is in understanding and accepting humanure and other organic materials as resource materials rather than waste materials. We have to stop thinking of human excrement and organic refuse as waste. When we do, then we'll stop defecating in our drinking water and stop sending our garbage to landfills.

It's critical that we separate water from humanure. As long as

we keep defecating in water we'll have a problem that we can't solve. The solution is to stop fouling our water, not to find new ways to clean it up. Don't use water as a vehicle for transporting human excrement or other waste. Humanure must be collected and composted along with other solid (and liquid) organic material produced by human beings. We won't be able to do this as long as we insist upon defecating into water. Granted, we can dehydrate the waterborne sewage sludge and compost that. However, this is a complicated, expensive, energy-intensive process. Furthermore, the sludge can be contaminated with all sorts of bad stuff from our sewers which can become concentrated in the compost.<sup>5</sup>

*M: Composting sewage sludge is bad?*

MS: No. In fact, composting is probably the best thing you can do with sludge. It's certainly a step in the right direction. There are many sludge composting operations around the world, and when the sludge is composted, it makes a useful soil additive. I've visited sludge composting sites in Nova Scotia, Pennsylvania, Ohio, and Montana, and the finished compost at all of the sites is quite impressive.

*M: It'll never happen (shaking his head). Face it. Americans, Westerners, will never stop shitting in water. They'll never, as a society, compost their manure. It's unrealistic. It's against our cultural upbringing. We're a society of hotdogs, hairspray and Ho-Hos, not composted humanure, fer chrissake. We don't believe in balancing human nutrient cycles! We just don't give a damn. Compost making is unglamorous and you can't get rich doing it. So why bother?!*

MS: You're right on one point — Americans will never stop shitting. But don't be so hasty. In 1988, in the United States alone, there were only 49 operating municipal sludge composting facilities.<sup>6</sup> By 1997, there were over 200.<sup>7</sup> The U.S. composting industry grew from less than 1,000 facilities in 1988 to nearly 3,800 in 2000 and that number will only increase.<sup>8</sup>

In Duisberg, Germany, a decades-old plant composts 100 tons of domestic refuse daily. Another plant at Bad Kreuznach handles twice that amount. Many European composting plants compost a mixture of refuse and sewage sludge. There are at least three composting plants in Egypt. In Munich, a scheme was being developed in 1990 to provide 40,000 households with "biobins" for the collection of compostable refuse.<sup>9</sup>

It's only a matter of time before the biobin concept is advanced to collect humanure as well. In fact, some composting toilets already are designed so that the humanure can be wheeled away and com-



Butler, Pennsylvania, U.S., sewage sludge composting facility (above).

Missoula, Montana, sewage sludge, after composting, is bagged and sold for home gardens (below).

A Nova Scotian compost operator inspects the windrow sewage sludge composting operation (bottom).

All photos by author.



posted at a separate site. Eventually, municipalities will assume the responsibility for collecting and composting all organic material from urban and suburban human populations, including toilet materials.

*M: Yeah, right.*

MS: And you are now revealing the main obstacle toward a sustainable society. Personal attitude. Everything we take for granted today — shoes, clothing, metal tools, electronic equipment, heck, even toilet paper, exists for one reason, and one reason only: because someone in the past cared about the future. You'd be running around naked today chasing rabbits with a stick if people in the past hadn't made things better for us in the present. We all have an obligation to our future generations. That's what evolution is and that's what survival of the species requires. We have to think ahead. We have to care about our descendants too, and not just about ourselves. That means we have to understand that waste is not good for us, or for future generations. When we dump endless amounts of garbage into the environment with the attitude that someone in the future can deal with it, we are not evolving, we're *devolving*.

*M: What's that supposed to mean?*

MS: It's simple enough. OK, you have trash. You don't throw the trash "out." There is no "out." It has to go somewhere. So you simply sort the trash into separate receptacles in your home, and that makes it easy to recycle the stuff. When it's recycled, it's not wasted. A chimpanzee could figure that out. It's easy to understand and it's easy to do.

A lot of compost that's been produced by big composting plants has been contaminated with things like batteries, metal shards, bottle caps, paints and heavy metals. As a result, much of it hasn't been useful for agriculture. Instead, it's been used for filler or for other non-agricultural applications, which, to me, is absurd. The way to keep junk out of compost is to value compostable material enough to collect it separately from other trash. A household biobin would do the trick. The biobin could be collected regularly, emptied, its contents composted, and the compost sold to farmers and gardeners as a financially self-supporting service provided by independent businesses.

The trick to successful large-scale compost production can be summed up in two words: *source separation*. The organic material must be separated at the source. This means that individual families will have to take some responsibility for the organic material they discard. They will no longer be permitted to throw it all in one garbage can with their plastic Ho-Ho wrappers, pop bottles, broken cell

phones and worn out toaster ovens. Organic material is too valuable to be wasted. The people in Nova Scotia have figured that out, as have many others throughout the world. Americans are a little slow.

*M: But they're not composting toilet materials, are they?*

MS: Some are composting sewage sludge, which is a big step in the right direction. Some entrepreneurs are in the sewage composting business in the United States, too. In 1989, the town of Fairfield, Connecticut, contracted to have its yard material and sewage sludge composted. The town is said to have saved at least \$100,000 in waste disposal costs in its first year of composting alone. The Fairfield operation is just a quarter mile from half million dollar homes and is reported to smell no worse than wet leaves from only a few yards away.<sup>10</sup> The EPA estimates that Americans will be producing 8.2 million tons of *biosolids* — that's another name for sewage sludge — by 2010 and that 70% of it will be recycled. Ironically, they only predict that 7% of that recycled sludge will be composted. Maybe the EPA will wake up before then and *smell the biosolids*.<sup>11</sup>

In Missoula, Montana, all of the city's sewage sludge is composted and the entire composting operation is funded by the tipping fees alone. All of the compost produced is pure profit and all of it is sold. Composting is a profitable venture when properly managed.

*M: But still, there's the fear of humanure and its capability of causing disease and harboring parasites.*

MS: That's right. But according to the literature, a biological temperature of 50°C (122°F) for a period of 24 hours is sufficient to kill the human pathogens potentially resident in humanure. EPA regulations require that a temperature of 55°C (131°F) be maintained for three days when composting sewage sludge in bins. Thermophilic microorganisms are everywhere, waiting to do what they do best — make compost. They're on grass, tree branches, leaves, banana peels, garbage and humanure. Creating thermophilic compost is not difficult or complicated and thermophilic composting is what we need to do in order to sanitize human excrement without excessive technology and energy consumption. Thermophilic composting is something humans all over the world can do whether or not they have money or technology.

There will always be people who will not be convinced that composted humanure is pathogen-free unless every tiny scrap of it is first analyzed in a laboratory, with negative results. On the other hand, there will always be people, like me, who conscientiously compost humanure by maintaining a well-managed compost pile, and who feel that their compost has been rendered hygienically safe as a result. A

layer of straw covering the finished compost pile, for example, will insulate the pile and help keep the outer surfaces from cooling prematurely. It's common sense, really. The true test comes in living with the composting system for long periods of time. I don't know anyone else who has done so, but after twenty six years, I've found that the simple system I use works well for me. And I don't do anything special or go to any great lengths to make compost, other than the simple things I've outlined in this book.

Perhaps Gotaas hits the nail on the head when he says, “*The farm, the garden, or the small village compost operator usually will not be concerned with detailed tests other than those to confirm that the material is safe from a health standpoint, which will be judged from the temperature, and that it is satisfactory for the soil, which will be judged by appearance. The temperature of the compost can be checked by: a) digging into the stack and feeling the temperature of the material; b) feeling the temperature of a rod after insertion into the material; or c) using a thermometer. Digging into the stack will give an approximate idea of the temperature. The material should feel very hot to the hand and be too hot to permit holding the hand in the pile for very long. Steam should emerge from the pile when opened. A metal or wooden rod inserted two feet (0.5 m) into the pile for a period of 5-10 minutes for metal and 10-15 minutes for wood should be quite hot to the touch, in fact, too hot to hold. These temperature testing techniques are satisfactory for the smaller village and farm composting operations.*”<sup>12</sup>

In other words, humanure composting can remain a simple process, achievable by anyone. It does not need to be a complicated, high-tech, expensive process controlled and regulated by nervous people in white coats bending over a compost pile, shaking their heads and wringing their hands while making nerdy clucking noises.

I want to make it clear though, that I can't be responsible for what other people do with their compost. If some people who read this book go about composting humanure in an irresponsible manner, they could run into problems. My guess is the worst thing that could happen is they would end up with a mouldered compost pile instead of a thermophilic one. The remedy for that would be to let the mouldered pile age for a couple years before using it agriculturally, or to use it horticulturally instead.

I can't fault someone for being fecophobic and I believe that fecophobia lies at the root of most of the concerns about composting humanure. What fecophobes may not understand is that those of us who aren't fecophobes understand the human nutrient cycle and the importance of recycling organic materials. We recycle organic refuse because we know it's the right thing to do, and we aren't hampered by

irrational fears. We also make compost because we need it for fortifying our food-producing soil and we consequently exercise a high degree of responsibility when making the compost. It's for our own good.

Then, of course, there's the composter's challenge to fecophobes: *show us a better way to deal with human excrement.*

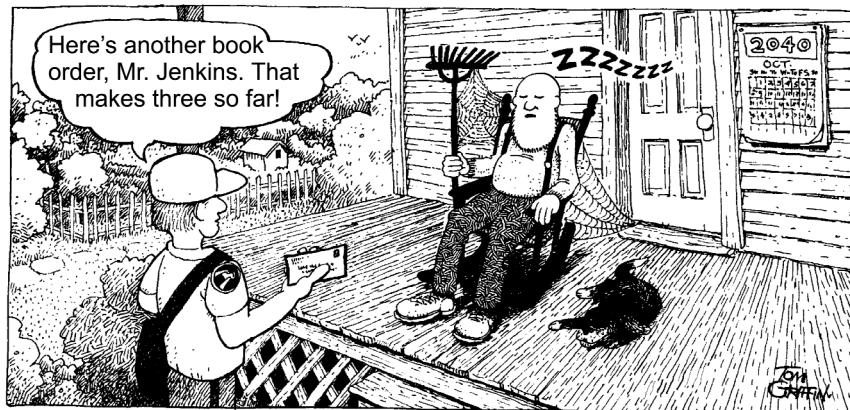
*M: Sounds to me like you have the final word on the topic of hum-nure.*

*MS: Hardly. The *Humanure Handbook* is only a tiny beginning in the dialogue about human nutrient recycling.*

*M: Well, sir, this is starting to get boring and our time is running out, so we'll have to wrap up this interview. Besides, I've heard enough talk about the world's most notorious "end" product. So let's focus a little on the end itself, which has now arrived.*

*MS: And this is it. This is the end?*

*M: "This is the end." (Sung like Jim Morrison.) What d'ya say folks?* (Wild applause, stamping of feet, frenzied whistling, audience jumping up and down, yanking at their hair, rolls of toilet paper are being thrown confetti-like through the air. Clothes are being torn off, people are cheering, screaming and foaming at the mouth. Someone starts chanting "Source separation, Source separation!" What's this!? The audience is charging the stage! The interviewee is being carried out over the heads of the crowd! Hot dang and hallelujah!)



### TEMPERATURE CONVERSIONS

<u>F</u>	<u>C</u>	<u>F</u>	<u>C</u>	<u>F</u>
-40	-40	150	65.55	0
-30	-34.44	140	60.00	5
-20	-28.88	130	54.44	10
-10	-23.33	120	48.8	15
0	-17.77	110	43.33	20
5	-15.00	100	37.77	25
10	-12.22	90	32.22	30
15	-9.44	80	26.66	35
20	-6.66	70	21.11	40
25	-3.88	60	15.55	45
30	-1.11	50	10.00	50
35	1.66	40	4.44	55
40	4.44	30	-1.11	60
45	7.22	20	-6.66	65
50	10.00			70
55	12.77			75
60	15.55			80
65	18.33			85
70	21.11			90
75	23.88			95
80	26.66			100
85	29.44			
90	32.22			
95	35.00			
98.6	36.99			
100	37.77			
105	40.55			
110	43.33			
115	46.11			
120	48.88			
125	51.66			
130	54.44			
135	57.22			
140	60.00			
145	62.77			
150	65.55			
155	68.33			
160	71.11			
165	73.88			

$$F^{\circ} = \frac{9}{5} C^{\circ} + 32$$

## THE HUMANURE HANDBOOK — GLOSSARY

- actinomycete** — Bacteria resembling fungi because they usually produce a characteristic, branched mycelium.
- activated sludge** — Sewage sludge that is treated by forcing air through it in order to activate the beneficial microbial populations resident in the sludge.
- aerobic** — Able to live, grow, or take place only where free oxygen is present, such as aerobic bacteria.
- algae** — Small aquatic plants.
- ambient air temperature** — The temperature of the surrounding air, such as the outdoor air temperature in the vicinity of a compost pile.
- amendment** — See “bulking agent.”
- anaerobic** — Able to live and grow where there is no oxygen.
- Ascaris** — A genus of roundworm parasitic to humans.
- Aspergillus fumigatus** — A spore-forming fungus that can cause allergic reactions in some people.
- bacteria** — One-celled microscopic organisms. Some are capable of causing disease in humans, others are capable of elevating the temperature of a pile of decomposing refuse sufficiently to destroy human pathogens.
- biochemical oxygen demand (BOD)** — The amount of oxygen used when organic matter undergoes decomposition by microorganisms. Testing for BOD is done to assess the amount of organic matter in water.
- blackwater** — Wastewater from a toilet.
- bulking agent** — An ingredient in compost, such as sawdust or straw, used to improve the structure, porosity, liquid absorption, odor, and carbon content. The terms “bulking agent” and “amendment” can be interchangeable.
- carbonaceous** — Containing carbon.
- carbon dioxide ( $CO_2$ )** — An inorganic gas composed of carbon and oxygen produced during composting.
- cellulose** — The principal component of cell walls of plants, composed of a long chain of tightly bound sugar molecules.
- C/N ratio** — The ratio of carbon to nitrogen in an organic material.
- combined sewers** — Sewers that collect both sewage and rain water runoff.
- compost** — A mixture of decomposing vegetable refuse, manure, etc., for fertilizing and conditioning soil.
- continuous composting** — A system of composting in which organic refuse material is continuously or daily added to the compost bin or pit.
- cryptosporidiosis** — A pathogenic protozoa which causes diarrhea in humans.
- curing** — Final stage of composting. Also called aging, or maturing.
- effluent** — Wastewater flowing from a source.
- enteric** — Intestinal.
- evapotranspiration** — The transfer of water from the soil into the atmosphere both by evaporation and by transpiration of the plants growing on the soil.
- fecal coliforms** — Generally harmless bacteria that are commonly found in the intestines of warm-blooded animals, used as an indicator of fecal contamination.
- fecophobia** — Fear of fecal material, especially in regard to the use of human fecal material for agricultural purposes.
- fungi** — Simple plants, often microscopic, that lack photosynthetic pigment.
- graywater** — Household drain water from sinks, tubs, and washing (not from toilets).
- green manure** — Vegetation grown to be used as fertilizer for the soil, either by direct application of the vegetation to the soil, by composting it before soil application, or by the leguminous fixing of nitrogen in the root nodules of the vegetation.
- heavy metal** — Metals such as lead, mercury, cadmium, etc., having more than five times the weight of water. When concentrated in the environment, can pose a significant health risk to humans.
- helminth** — A worm or worm-like animal, especially parasitic worms of the human digestive system, such as the roundworm or hookworm.
- human nutrient cycle** — The repeating cyclical movement of nutrients from soil to plants and animals, to humans, and back to soil.
- humanure** — Human feces and urine composted for agriculture purposes.
- humus** — A dark, loamy, organic material resulting from the decay of plant and animal refuse.
- hygiene** — Sanitary practices, cleanliness.
- indicator pathogen** — A pathogen whose occurrence serves as evidence that certain environmental conditions, such as pollution, are present.
- K** — Chemical symbol for potassium.
- latrine** — A toilet, often for the use of a large number of people.
- leachate** — Any liquid draining from a source. Pertaining to compost, it is the liquid that drains from organic material, especially when rain water comes in contact with the compost.
- lignin** — A substance that forms the woody cell walls of plants and the “cement” between them. Lignin is found together with cellulose and is resistant to biological decomposition.

- macroorganism** — An organism which, unlike a microorganism, can be seen by the naked eye, such as an earthworm.
- mesophile** — Microorganisms which thrive at medium temperatures (20-37°C or 68-99°F).
- metric tonne** — A measure of weight equal to 1,000 kilograms or 2,204.62 pounds.
- microhusbandry** — The cultivation of microscopic organisms for the purpose of benefiting humanity, such as in the production of fermented foods, or in the decomposition of organic refuse materials.
- microorganism** — An organism that needs to be magnified in order to be seen by the human eye.
- moulder (also molder)** — To slowly decay, generally at temperatures below that of the human body.
- mulch** — Organic material, such as leaves or straw, spread on the ground around plants to hold in moisture, smother weeds, and feed the soil.
- municipal solid waste (MSW)** — Solid waste originating from homes, industries, businesses, demolition, land clearing, and construction.
- mycelium** — Fungus filaments or hyphae.
- N** — Chemical symbol for nitrogen.
- naturalchemy** — The transformation of seemingly valueless materials into materials of high value using only natural processes, such as the conversion of manure into humus by means of microbial activity.
- night soil** — Human excrement used raw as a soil fertilizer.
- nitrates** — A salt or ester of nitric acid, such as potassium nitrate or sodium nitrate, both used as fertilizers, and which show up in water supplies as pollution.
- organic** — Referring to a material from an animal or vegetable source, such as refuse in the form of manure or food scraps; also a form of agriculture which employs fertilizers and soil conditioners that are primarily derived from animal or vegetable sources as opposed to mineral or petrochemical sources.
- P** — Chemical symbol for phosphorous.
- pathogen** — A disease-causing microorganism.
- PCB** — Polychlorinated biphenyl, a persistent and pervasive environmental contaminant.
- peat moss** — Organic matter that is under-decomposed or slightly decomposed originating under conditions of excessive moisture such as in a bog.
- pH** — A symbol for the degree of acidity or alkalinity in a solution, ranging in value from 1 to 14. Below 7 is acidic, above 7 is alkaline, 7 is neutral.
- phytotoxic** — Toxic to plants.
- pit latrine** — A hole or pit into which human excrement is deposited. Known as an out-house or privy when sheltered by a small building.
- protozoa** — Tiny, mostly microscopic animals each consisting of a single cell or a group of more or less identical cells, and living primarily in water. Some are human pathogens.
- psychrophile** — Microorganism which thrives at low temperatures [as low as -10°C (14°F), but optimally above 20°C (68°F)].
- schistosome** — Any genus of flukes that live as parasites in the blood vessels of mammals, including humans.
- septage** — The organic material pumped from septic tanks.
- septic** — Causing or resulting from putrefaction (foul-smelling decomposition).
- shigella** — Rod-shaped bacteria, certain species of which cause dysentery.
- sludge** — The heavy sediment in a sewage or septic tank. Also called biosolids.
- source separation** — The separation of discarded material by specific material type at the point of generation.
- sustainable** — Able to be continued indefinitely without a significant negative impact on the environment or its inhabitants.
- thermophilic** — Characterized by having an affinity for high temperatures (above 40.5°C or 105°F), or for being able to generate high temperatures.
- tipping fee** — The fee charged to dispose of refuse material.
- vector** — A route of transmission of pathogens from a source to a victim. Vectors can be insects, birds, dogs, rodents, or vermin.
- vermicomposting** — The conversion of organic material into worm castings by earthworms.
- vermin** — Objectionable pests, usually of a small size, such as flies, mice, and rats, etc..
- virus** — Any group of submicroscopic pathogens which multiply only in connection with living cells.
- waste** — A substance or material with no inherent value or usefulness, or a substance or material discarded despite its inherent value or usefulness.
- wastewater** — Water discarded as waste, often polluted with human excrements or other human pollutants, and discharged into any of various wastewater treatment systems, if not directly into the environment.
- Western** — Of or pertaining to the Western hemisphere (which includes North and South America and Europe) or its human inhabitants.
- windowrow** — A long, narrow pile of compost.
- worm castings** — Earthworm excrement. Worm castings appear dark and granular like soil, and are rich in soil nutrients.
- yard material** — Leaves, grass clippings, garden materials, hedge clippings, and brush.

## HUMANURE HANDBOOK — REFERENCE CITATIONS

### REFERENCES — CHAPTER ONE — CRAP HAPPENS

- 1 - State of the World 1999, p. 10; State of the World 1998, p. 3.
- 2 - Brown, Lester R., et al. (1998). Vital Signs 1998. New York: W. W. Norton and Co., p. 20.
- 3 - State of the World 1998, p. 4, 5.
- 4 - State of the World 1998, p. 14.
- 5 - State of the World 1998, p. 11, 41; State of the World 1999, p. 97.
- 6 - State of the World 1999, p. 13, 97.
- 7 - State of the World 1999, p. 20, 21, 41, 46.

### REFERENCES — CHAPTER TWO — WASTE NOT WANT NOT

- 1 - Too Good to Throw Away, Chapter Two.
- 2 - Brown, Lester R., et al. (1998). State of the World 1998. New York: W. W. Norton and Co., p. 106.
- 3 - Kantor, Linda S., et al. (1997, January - April). "Estimating and Addressing America's Food Losses." Food Review. Washington, D.C.: US Department of Agriculture, Commodity Economics Division, Economic Research Service.
- 4 - US Environmental Protection Agency. (May 1998) Characterization of Municipal Solid Waste in the United States: 1997 Update. Report # EPA530-R-98-007. Washington, D.C.: US Environmental Protection Agency, p. 29, 45.
- 5 - State of the World 1998, p. 102.
- 6 - State of the World 1998, p. 101, 166.
- 7 - Environment Reporter. (1996 September 27)
- 8 - Too Good to Throw Away, Chapter Two.
- 9 - Too Good to Throw Away, Chapter Two.
- 10 - World Resource Foundation. (1998, April). Warmer Bulletin Information Sheet - Landfill.  
17 - Daniel, J.E., et al., (Eds.). 1992 Earth Journal. Boulder, CO: Buzzworm Books, p. 94.
- 11 - Fahm, Lattee A. (1980). The Waste of Nations: The Economic Utilization of Human Waste in Agriculture. Montclair, NJ: Allenheld, Osmun & Co., p. 45.
- 12 - Golden, Jack, et al. (1979). The Environmental Impact Data Book. Ann Arbor, MI: Ann Arbor Science Publishers, Inc., p. 495.
- 13 - US Department of Commerce, National Oceanic and Atmospheric Administration, Office of Ocean Resources, Conservation and Assessment. (1987). The National Coastal Pollutant Discharge Inventory Database. Silver Spring, MD: DOC/NOAA/ORCA.
- 14 - Environment Reporter. (1992 July 31). Washington D.C.: Bureau of National Affairs, Inc., p. 1110.
- 15 - Paul, Elizabeth. (1998). Testing the Waters VIII: Has Your Vacation Beach Cleaned Up Its Act?. Washington, D.C.: Natural Resources Defense Council, Inc.; NRDC Worldview News. (1998). Pollution Persists at US Beaches. Washington, D.C.: Natural Resources Defense Council, Inc.
- 16 - Whitaker, Barbara. Federal Judge Rules Los Angeles Violates Clean Water Laws. N. Y. Times, Dec. 24, 2002
- 17 - Bitton, Gabriel. (1994). Wastewater Microbiology. New York: Wiley-Liss, Inc., p. 368-369.
- 18 - National Resources Defense Council. (1997). Bulletin: Stop Polluted Runoff - 11 Actions to Clean up Our Waters. <http://www.nrdc.org/nrdcpn/fppubl.html>.
- 19 - Wastewater Microbiology, p. 86.
- 20 - Ralof, Janet. (1998 March 21). "Drugged Waters — Does it Matter that Pharmaceuticals are Turning Up in Water Supplies?" Science News, Vol. 153 (No. 12), p. 187-189.
- 21 - State of the New England Environment. (1996). Preserving New England Natural Resources. <http://www.epa.gov/region01/soe/coastal.html>.
- 22 - Toward Organic Security: Environmental Restoration or the Arms Race?. Peace and Environment Platform Project, c/o World Citizens Assembly, Suite 506, 312 Sutter St., San Francisco, CA 94018.
- 23 - Vital Signs 1998, p. 156.
- 24 - Courier. (1985, January). UNESCO. 7 Place de Fentonoy, 75700 Paris, France.
- 25 - State of the World 1999, p. 137.
- 26 - Vital Signs 1998, p. 156.
- 27 - Gever, John, et al. (1986). Beyond Oil: The Threat to Food and Fuel in the Coming Decades... A Summary Report. Cambridge, MA: Ballinger Publishing Co.
- 28 - Solley, Wayne B., et al. (1990). "Estimated Water Use in the United States in 1990." US Geological Survey Circular 1081, Table 31. Denver, CO. United State Geological Service, p. 65.
- 29 - National Resources Defense Council. (1996 December 24). Population and Consumption at NRDC: US Population Scorecard. Washington, D.C.: National Resources Defense Council.
- 30 - The Waste of Nations, p. xxiv.
- 31 - 1993 Information Please Environmental Almanac, p. 340-341.
- 32 - Environment Reporter. (1992 April 24) p. 2877-78.
- 33 - State of the World 1998, p. 100.
- 34 - Sides, S. (1991, August/September). "Compost." Mother Earth News, Issue 127, p. 50.
- 35 - Brown, Lester R., et al. (1998). Vital Signs 1998. New York: W. W. Norton and Co., p. 44-45.
- 36 - Vital Signs, p. 44.
- 37 - Vital Signs, p. 132.
- 38 - Vital Signs 1998, p. 132.
- 39 - State of the World 1999, p. 135.
- 40 - State of the World 1990, p. 184.
- 41 - Rybczynski, Witold, et al. (1982). Low Cost Technology Options for Sanitation - A State of the Art Review and Annotated Bibliography. Washington, D.C.: World Bank, p. 23.
- 42 - Cannon, Charles A. (1997 September 3-5). "Life Cycle Analysis and Sustainability Moving Beyond the Three

R's — Reduce, Reuse, and Recycle — to P2R2 — Preserve, Purify, Restore and Remediate." In E.I. Stentiford (Ed.), *Proceedings of the 1997 Organic Recovery and Biological Treatment International Conference*. Harrogate, UK, p. 252-253. Available from Stuart Brown, National Compost Development Association, PO Box 4, Grassington, North Yorkshire, BD23 5UR UK (stuartbrown@compuserve.com)

#### REFERENCES — CHAPTER THREE — MICROHUSBANDRY

- 1 - Shuval, Hillel I. et al. (1981). *Appropriate Technology for Water Supply and Sanitation - Night Soil Composting*. p.2. International Bank for Reconstruction and Development (World Bank), Washington DC, 20433, USA.
- 2 - Shuval, Hillel I., et al. (1981). *Appropriate Technology for Water Supply and Sanitation - Night Soil Composting*. p.2. International Bank for Reconstruction and Development (World Bank), Washington DC, 20433, USA.
- 3 - Shuval, Hillel I. et al. (1981). *Appropriate Technology for Water Supply and Sanitation - Night Soil Composting*. p.ii. International Bank for Reconstruction and Development (World Bank), Washington DC, 20433, USA.
- 4 - Rodale, J. I. (1960). *The Complete Book of Composting*. p. 9. Rodale Books, Inc., Emmaus, PA.
- 5 - Sides, S. (1991). *Compost. Mother Earth News*. Issue 127, Aug/Sept 1991 (pp.49-53).
- 6 - Bem, R., (1978). *Everyone's Guide to Home Composting*. Van Nostrand Reinhold Co., NY (p.4).
- 7 - Haug, Roger T. (1993). *The Practical Handbook of Compost Engineering*. p. 2. CRC Press, Inc., 2000 Corporate Blvd. N.W., Boca Raton, FL 33431 USA.
- 8 - Cannon, Charles A., (1997). *Life Cycle Analysis and Sustainability Moving Beyond the Three R's - Reduce, Reuse, and Recycle - to P2R2 - Preserve, Purify, Restore and Remediate*. As seen in the 1997 Organic Recovery and Biological Treatment Proceedings, Stentiford, E.I. (ed.). International Conference, Harrogate, United Kingdom. 3-5 September, 1997. P. 253. Available from Stuart Brown, National Compost Development Association, PO Box 4, Grassington, North Yorkshire, BD23 5UR UK (stuartbrown@compuserve.com).
- 9 - Howard, Sir Albert, (1943). *An Agricultural Testament*. Oxford University Press: New York.
- 10 - Bhamidimari, R. (1988). *Alternative Waste Treatment Systems*. Elsevier Applied Science Publishers LTD., Crown House, Linton Road, Barking, Essex, IG11 8JU, England. (p.129).
- 11 - Rynk, Robert, ed. (1992). *On-Farm Composting Handbook*. Northeast Regional Agricultural Engineering Service. Ph: (607) 255-7654. p. 12.
- 12 - Haug, Roger T. (1993). *The Practical Handbook of Compost Engineering*. p. 2. CRC Press, Inc., 2000 Corporate Blvd. N.W., Boca Raton, FL 33431 USA.
- 13 - Palmisano, Anna C. and Barlaz, Morton A. (Eds.) (1996). *Microbiology of Solid Waste*. P. 129. CRC Press, Inc., 2000 Corporate Blvd., N.W., Boca Raton, FL 33431 USA.
- 14 - Howard, Sir Albert, (1943). *An Agricultural Testament*. (p.48).
- 15 - Ingham, Elaine (1998). *Anaerobic Bacteria and Compost Tea*. Biocycle, June 1998, p 86. The JG Press, Inc., 419 State Avenue, Emmaus, PA 18049.
- 16 - Stoner, C.H. (Ed.). (1977). *Goodbye to the Flush Toilet*. Rodale Press: Emmaus, PA, 1977. (p.46).
- 17 - Rodale, J.I. et al. (Eds.). (1960). *The Complete Book of Composting*. Rodale Books Inc.: Emmaus, Pa (pp.646-647).
- 18 - Gotaas, Harold B., (1956). *Composting - Sanitary Disposal and Reclamation of Organic Wastes*. p.39. World Health Organization, Monograph Series Number 31. Geneva.
- 19 - *Mixing Browns and Greens For Backyard Success*. Biocycle, Journal of Composting and Recycling, January 1998. p. 20 (Regional Roundup). JG Press, Inc., 419 State Ave., Emmaus, PA 18049 USA.
- 20 - Brock, Thomas D. (1986). *Thermophiles - General, Molecular, and Applied Biology*. p.4. John Wiley and Sons, Inc.
- 21 - Madigan, Michael T. et al. (1997). *Brock Biology of Microorganisms*, Eighth edition. Pp. 150, 167. Information about water heaters, as well as temperature ranges of bacteria.
- 22 - Waksman, S.A. (1952). *Soil Microbiology*. John Wiley and Sons, Inc., New York. (p.70).
- 23 - Rynk, Robert, ed. (1992). *On-Farm Composting Handbook*. Northeast Regional Agricultural Engineering Service. Ph: (607) 255-7654. p. 55.
- 24 - Thimann, K.V. (1955). *The Life of Bacteria: Their Growth, Metabolism, and Relationships*. The Macmillan Co., New York. (p.177).
- 25 - Wade, Nicholas (1996). *Universal Ancestor*. The New York Times, as seen in the Pittsburgh Post-Gazette, Monday, August 26, 1996, p. A-8.
- 26 - Brock, Thomas D. (1986). *Thermophiles - General, Molecular, and Applied Biology*. p.23. John Wiley and Sons, Inc.
- 27 - Bitton, Gabriel (1994). *Wastewater Microbiology*. p. 81. Wiley-Liss, Inc. 605 Third Avenue, New York, NY 10518-0012.
- 28 - Ibid. (p. 212)
- 29 - Palmisano, Anna C. and Barlaz, Morton A. (Eds.) (1996). *Microbiology of Solid Waste*. P. 123. CRC Press, Inc., 2000 Corporate Blvd., N.W., Boca Raton, FL 33431 USA.
- 30 - Lynch, J.M. and Poole, N.L. (Eds.). (1979). *Microbial Ecology: A Conceptual Approach*. Blackwell Scientific Publications, London. (p.238).
- 31 - Sterritt, Robert M. (1988). *Microbiology for Environmental and Public Health Engineers*. P. 53. E. & F. N. Spon Ltd., New York, NY 10001 USA.
- 32 - Palmisano, Anna C. and Barlaz, Morton A. (Eds.) (1996). *Microbiology of Solid Waste*. Pp. 124, 125, 129, 133. CRC Press, Inc., 2000 Corporate Blvd., N.W., Boca Raton, FL 33431 USA.
- 33 - Ingham, Elaine (1998). *Replacing Methyl Bromide with Compost*. Biocycle, Journal of Composting and Recycling, December 1998. p. 80. JG Press, Inc., 419 State Ave., Emmaus, PA 18049 USA.
- 34 - Curry, Dr. Robin (1977). Composting of Source Separated Domestic Organic Waste by Mechanically Turned Open Air Windrowing. As seen in the 1997 Organic Recovery and Biological Treatment Proceedings, Stentiford, E.I. (ed.). International Conference, Harrogate, United Kingdom. 3-5 September, 1997. P. 184.
- 35 - *Applied Microbiology*, December 1969.
- 36 - Gotaas, Harold B., (1956). *Composting - Sanitary Disposal and Reclamation of Organic Wastes*. (p.20). World Health Organization, Monograph Series Number 31. Geneva.
- 37 - Curry, Dr. Robin (1977). Composting of Source Separated Domestic Organic Waste by Mechanically Turned Open Air Windrowing. As seen in the 1997 Organic Recovery and Biological Treatment Proceedings, Stentiford, E.I. (ed.). International Conference, Harrogate, United Kingdom. 3-5 September, 1997. P. 183.
- 38 - Palmisano, Anna C. and Barlaz, Morton A. (Eds.) (1996). *Microbiology of Solid Waste*. P. 169. CRC Press, Inc., 2000 Corporate Blvd., N.W., Boca Raton, FL 33431 USA.

- 39 - Palmisano, Anna C. and Barlaz, Morton A. (Eds.) (1996). *Microbiology of Solid Waste*. Pp. 121, 124, 134. CRC Press, Inc., 2000 Corporate Blvd., N.W., Boca Raton, FL 33431 USA.
- 40 - Rodale, J. I. (1960). *The Complete Book of Composting*. p. 702. Rodale Books, Inc., Emmaus, PA.
- 41 - Curry, Dr. Robin (1977). Composting of Source Separated Domestic Organic Waste by Mechanically Turned Open Air Windrowing. As seen in the 1997 Organic Recovery and Biological Treatment Proceedings, Stentiford, E.I. (ed.). International Conference, Harrogate, United Kingdom, 3-5 September, 1997. P. 183.
- 42 - Brock, Thomas D. (1986). *Thermophiles — General, Molecular, and Applied Biology*. p.244. John Wiley and Sons.
- 43 - Rynk, Robert, ed. (1992). *On-Farm Composting Handbook*. Northeast Regional Agricultural Engineering Service. Ph: (607) 255-7654. p. 13.
- 44 - *Biocycle*, November 1998, p.18.
- 45 - Rodale, J. I. (1960). *The Complete Book of Composting*. p. 932. Rodale Books, Inc., Emmaus, PA.
- 46 - Smalley, Curtis (1998). *Hard Earned Lessons on Odor Management*. Biocycle, Journal of Composting and Recycling, January 1998. p. 59. JG Press, Inc., 419 State Ave., Emmaus, PA 18049 USA.
- 47 - Brinton, William F. Jr. (date unknown). *Sustainability of Modern Composting - Intensification Versus Cost and Quality*. Woods End Institute, PO Box 297, Mt. Vernon, Maine 04352 USA.
- 48 - Brinton, William F. Jr. (date unknown). *Sustainability of Modern Composting - Intensification Versus Cost and Quality*. Woods End Institute, PO Box 297, Mt. Vernon, Maine 04352 USA.
- 49 - Palmisano, Anna C. and Barlaz, Morton A. (Eds.) (1996). *Microbiology of Solid Waste*. P. 170. CRC Press, Inc., 2000 Corporate Blvd., N.W., Boca Raton, FL 33431 USA.
- 50 - *Researchers Study Composting in the Cold*. Biocycle, Journal of Composting and Recycling, January 1998. p. 24 (Regional Roundup). JG Press, Inc., 419 State Ave., Emmaus, PA 18049 USA.
- 51 - Gotaas, Harold B., (1956). *Composting - Sanitary Disposal and Reclamation of Organic Wastes*. p.77. World Health Organization, Monograph Series Number 31. Geneva.
- 52 - Regan, Raymond W. (1998). *Approaching 50 years of Compost Research*. Biocycle, Journal of Composting and Recycling, October 1998. p. 82. JG Press, Inc., 419 State Ave., Emmaus, PA 18049 USA.
- 53 - Howard, Sir Albert (1943). *An Agricultural Testament*. Oxford University Press: New York. (p.44).Also see: Rodale, J.I. (1946). *Pay Dirt*. The Devon-Adair Co.: New York.
- 54 - Rodale, J.I. et al. (Eds.) (1960). *The Complete Book of Composting*. Rodale Books Inc.: Emmaus, PA (p.658).
- 55 - Regan, Raymond W. (1998). *Approaching 50 years of Compost Research*. Biocycle, Journal of Composting and Recycling, October 1998. p. 82. JG Press, Inc., 419 State Ave., Emmaus, PA 18049 USA.
- 56 - Poncavage, J. and Jesiolowski, J. (1991). Mix Up a Compost and a Lime. *Organic Gardening*. March 1991, Vol. 38, Issue 3. (p.18).
- 57 - Gotaas, Harold B., (1956). *Composting - Sanitary Disposal and Reclamation of Organic Wastes*. p.93. World Health Organization, Monograph Series Number 31. Geneva.
- 58 - Palmisano, Anna C. and Barlaz, Morton A. (Eds.) (1996). *Microbiology of Solid Waste*. P. 132. CRC Press, Inc., 2000 Corporate Blvd., N.W., Boca Raton, FL 33431 USA.
- 59 - US EPA (1998). *An Analysis of Composting as an Environmental Remediation Technology*. EPA530-B-98-001, March 1998.
- 60 - Haug, Roger T. (1993). *The Practical Handbook of Compost Engineering*. p. 9. CRC Press, Inc., 2000 Corporate Blvd. N.W., Boca Raton, FL 33431 USA.
- 61 - US EPA (Oct 1997). *Innovative Uses of Compost - Bioremediation and Pollution Prevention*. EPA530-F-97-042.
- 62 - US EPA (1998). *An Analysis of Composting as an Environmental Remediation Technology*. EPA530-B-98-001, March 1998.
- 63 - Cannon, Charles A., (1997). Life Cycle Analysis and Sustainability Moving Beyond the Three R's - Reduce, Reuse, and Recycle - to P2R2 - Preserve, Purify, Restore and Remediate. As seen in the 1997 Organic Recovery and Biological Treatment Proceedings, Stentiford, E.I. (ed.). International Conference, Harrogate, United Kingdom, 3-5 September, 1997. P. 253. Available from Stuart Brown, National Compost Development Association, PO Box 4, Grassington, North Yorkshire, BD23 5UR UK (stuartbrown@compuserve.com).
- 64 - US EPA (October 1997). *Innovative Uses of Compost - Bioremediation and Pollution Prevention*. EPA530-F-97-042.
- 65 - Logan, W.B. (1991). "Rot is Hot." *New York Times Magazine*. 9/8/91, Vol. 140, Issue 4871. (p.46).
- 66 - *Compost Fungi Used to Recover Wastepaper*. Biocycle, Journal of Composting and Recycling, May 1998. p. 6 (Biocycle World). JG Press, Inc., 419 State Ave., Emmaus, PA 18049 USA.
- 67 - Young, Lily Y., and Cerniglia, Carl E. (Eds.) (1995). *Microbial Transformation and Degradation of Toxic Organic Chemicals*. Pp. 408, 461, and Table 12.5. Wiley-Liss, Inc. 605 Third Avenue, New York, NY 10518-0012.
- 68 - Palmisano, Anna C. and Barlaz, Morton A. (Eds.) (1996). *Microbiology of Solid Waste*. P. 127. CRC Press, Inc., 2000 Corporate Blvd., N.W., Boca Raton, FL 33431 USA.
- 69 - Logan, W.B. (1991). "Rot is Hot." *New York Times Magazine*. 9/8/91, Vol. 140, Issue 4871. (p.46).
- 70 - Lubke, Sigfried. (1989). Interview: All Things Considered in the Wake of the Chernobyl Nuclear Accident. *Acres U.S.A.* December 1989. (p. 20) [also contact Uta and Sigfried Lubke, A4722 Peuerbach, Untererleinsbach 1, Austria]
- 71 - US EPA (1998). *An Analysis of Composting as an Environmental Remediation Technology*. EPA530-B-98-001, March 1998.
- 72 - Cannon, Charles A., (1997). Life Cycle Analysis and Sustainability Moving Beyond the Three R's - Reduce, Reuse, and Recycle - to P2R2 - Preserve, Purify, Restore and Remediate. As seen in the 1997 Organic Recovery and Biological Treatment Proceedings, Stentiford, E.I. (ed.). International Conference, Harrogate, United Kingdom, 3-5 September, 1997. P. 254. Available from Stuart Brown, National Compost Development Association, PO Box 4, Grassington, North Yorkshire, BD23 5UR UK (stuartbrown@compuserve.com).
- and Schonberner, Doug (1998). *Reclaiming Contaminated Soils*, as well as Block, Dave (1998). *Composting Breaks Down Explosives*. Biocycle, Journal of Composting and Recycling, September 1998, 36-40.
- 73 - US EPA (1998). *An Analysis of Composting as an Environmental Remediation Technology*. EPA530-B-98-001, March 1998.
- 74 - Block, Dave (1998). *Degrading PCB's Through Composting*. Biocycle, Journal of Composting and Recycling, December 1998. p. 45-48. JG Press, Inc., 419 State Ave., Emmaus, PA 18049 USA.
- 75 - US EPA (October 1997). *Innovative Uses of Compost - Bioremediation and Pollution Prevention*. EPA530-F-97-042.
- 76 - US EPA (October 1997). *Innovative Uses of Compost - Bioremediation and Pollution Prevention*. EPA530-F-97-042.

- 77 - Rynk, Robert, ed. (1992). On-Farm Composting Handbook. Northeast Regional Agricultural Engineering Service. Ph: (607) 255-7654. p. 83.
- 78 - Hoitink, Harry A. J. et al., (1997). Suppression of Root and Foliar Diseases Induced by Composts. As seen in the 1997 Organic Recovery and Biological Treatment Proceedings, Stentiford, E.I. (ed.). International Conference, Harrogate, United Kingdom. 3-5 September, 1997. p. 95.
- 79 - US EPA (October 1997). *Innovative Uses of Compost - Disease Control for Plants and Animals*. EPA530-F-97-044.
- 80 - US EPA (1998). *An Analysis of Composting as an Environmental Remediation Technology*. EPA530-B-98-001, March 1998.
- 81 - Logan, W.B. (1991). Rot is Hot. *New York Times Magazine*. 9/8/91, Vol. 140, Issue 4871. (p.46).
- 82 - US EPA (1998). *An Analysis of Composting as an Environmental Remediation Technology*. EPA530-B-98-001, March 1998.
- 83 - Trankner, Andreas, and Brinton, William (date unknown). *Compost Practices for Control of Grape Powdery Mildew (*Uncinula necator*)*. Woods End Institute, PO Box 297, Mt. Vernon, Maine 04352 USA.
- 84 - Quote from Elaine Ingham as reported in: Grobe, Karin (1998). *Fine-Tuning the Soil Web*. Biocycle, Journal of Composting and Recycling, January 1998. p. 46. JG Press, Inc., 419 State Ave., Emmaus, PA 18049 USA.
- 85 - Sides, S. (1991). Compost. *Mother Earth News*. Issue 127, Aug/Sept 1991 (p.50).
- 86 - US EPA (October 1997). *Innovative Uses of Compost - Disease Control for Plants and Animals*. EPA530-F-97-044.
- 87 - Biocycle, Journal of Composting and Recycling, October 1998. p. 26. JG Press, Inc., 419 State Ave., Emmaus, PA 18049 USA.
- 88 - US EPA (October 1997). *Innovative Uses of Compost - Disease Control for Plants and Animals*. EPA530-F-97-044.
- 89 - Brodie, Herbert L., and Carr, Lewis E. (1997). Composting Animal Mortality. As seen in the 1997 Organic Recovery and Biological Treatment Proceedings, Stentiford, E.I. (ed.). International Conference, Harrogate, United Kingdom. 3-5 September, 1997. Pp. 155-159.
- 90 - McKay, Bart (1998). *Com-Postal-Ing in Texas*. Biocycle, Journal of Composting and Recycling, May 1998. p. 44-46. JG Press, Inc., 419 State Ave., Emmaus, PA 18049 USA.
- 91 - *Garbage: the Practical Journal for the Environment*. May/June 1992, p.66, Old House Journal Corp., 2 Main St., Gloucester, MA 01930.
- 92 - Logan, W.B. (1991). "Rot is Hot." *New York Times Magazine*. 9/8/91, Vol. 140, Issue 4871.
- 93 - Biocycle, Journal of Composting and Recycling, November 1998. p. 18. JG Press, Inc., 419 State Ave., Emmaus, PA 18049 USA.
- XX - For more information see: <http://www.deq.state.or.us/wmc/solwaste/documents/Clopyralid%20Study.pdf>

#### REFERENCES — CHAPTER FOUR — DEEP SHIT

- 1 - Bulletin of the Atomic Scientists. September/October 1998.
- 2 - Rodale, J. I. (1946). *Paydirt*. Devon-Adair Co.: NY, (p.vi).
- 3 - *Beyond Oil: The Threat to Food and Fuel in the Coming Decades, A summary Report*. November 1986. Carrying Capacity Inc., 1325 G. Street, NW, Suite 1003, Wash. D.C. 10005.
- 4 - King, F.H. (1911). *Farmers of Forty Centuries*. Rodale Press: Emmaus, PA 18049.
- 5 - Ibid. (p.193, 196-7).
- 6 - Ibid. (p.10).
- 7 - Ibid. (p.19).
- 8 - Ibid. (p.199).
- 9 - White, A.D. (1955). *The Warfare of Science with Theology*. George Braziller: New York. (pp.68,70).
- 10 - Ibid. (p.69).
- 11 - Ibid. (p.71).
- 12 - Ibid. (p.73).
- 13 - Ibid. (pp.76-77).
- 14 - Ibid. (p.84).
- 15 - Ibid. (p.85).
- 16 - Reyburn, Wallace (1989). *Flushed with Pride - The Story of Thomas Crapper*. Pavilion Books Limited, 196 Shaftesbury Avenue, London WC2H 8JL. pp. 24-25.
- 17 - Seaman, L.C.B. (1973). *Victorian England*. Methuen & Co.: London. (pp. 48-56).
- 18 - Shuval, Hillel I. et al. (1981). *Appropriate Technology for Water Supply and Sanitation - Night Soil Composting*. Abstract. World Bank, Washington DC 20433, USA.
- 19 - Winblad, Uno, and Kilama, Wen (1985). *Sanitation Without Water*. Macmillan Education Ltd., London and Basingstoke. p. 12.
- 20 - Edmonds, Richard Louis (1994). *Patterns of China's Lost Harmony - A Survey of the Country's Environmental Degradation and Protection*. p. 9, 132, 137, 142, 146, 156. Routledge, 11 New Fetter Lane, London EC4P 4EE and 29 West 35th Street, New York, NY 10001.
- 21 - Hoitink, Harry A. J. et al., (1997). Suppression of Root and Foliar Diseases Induced by Composts. As seen in the 1997 Organic Recovery and Biological Treatment Proceedings, Stentiford, E.I. (ed.). International Conference, Harrogate, United Kingdom. 3-5 September, 1997. p. 97.
- 22 - *Farmers of Forty Centuries*. (p.198).

#### REFERENCES — CHAPTER FIVE — A DAY IN THE LIFE OF A TURD

- 1 - Manci, K. *Septic Tank - Soil Absorption Systems*. Agricultural Engineering Fact Sheet SW-44. Penn State College of Agriculture Cooperative Extension, University Park, PA 16802.
- 2 - Manci, K. *Mound Systems for Wastewater Treatment*. SW-43. Same as above.
- 3 - Stewart, John G. (1990). *Drinking Water Hazards: How to Know if There Are Toxic Chemicals in Your Water and What to Do If There Are*. Envirographics: Hiram, Ohio. (pp.177-178).
- 4 - van der Leeden, F. et al. (1990). *The Water Encyclopedia*. Lewis Publishers Inc.: Chelsea, Michigan, 48118. (p.526).
- 5 - Ibid. (p.525).
- 6 - Stewart, John G. (as in #3 above, same pages).

- 7 - Ibid.
- 8 - *Environment Reporter*. 2/28/92. The Bureau of National Affairs, Inc., Washington D.C., (pp. 2441-2).
- 9 - Gray, N.F. (1990). *Activated Sludge Theory and Practice*. Oxford University Press: New York. (p.125).
- 10 - *Journal of Environmental Health*. July/August 1989. "EPA Proposes New Rules for Sewage Sludge Disposal". (P.321).
- 11 - Logan, W.B. (1991). "Rot is Hot." *New York Times Magazine*. 9/8/91 Vol. 140, Issue 4871, p.46.
- 12 - van der Leeden, F. et al. (1990). *The Water Encyclopedia Second Edition*. Lewis Publishers, 121 South Main Street, Chelsea, Michigan 48118 (p. 541).
- 13 - *Garbage*. February/March 1993. Old House Journal Corp., 2 Main St., Gloucester, MA 01930. (p.18).
- 14 - Pickford, John (1995). *Low-Cost Sanitation - A Survey of Practical Experience*. p. 96. IT Publications, 103-105 Southampton Row, London WC1B 4HH, UK.
- 15 - US EPA (1996). *Wastewater Treatment: Alternatives to Septic Systems (Guidance Document)*. EPA/909-K-96-001. US Environmental Protection Agency, Region 9, Drinking Water Program (W-6-3). p. 16-19. and:  
US EPA (1987). *It's Your Choice - A Guidebook for Local Officials on Small Community Wastewater Management Options*. EPA 430/9-87-006. United States Environmental Protection Agency, Office of Municipal Pollution Control (WH-595), Municipal Facilities Division, Washington DC 20460. p.55.
- 16 - Manahan, S.E. (1990). *Hazardous Waste Chemistry, Toxicology and Treatment*. Lewis Publishers, Inc.: Chelsea, Michigan. (p.131).
- 17 - Bitton, Gabriel (1994). *Wastewater Microbiology*. p. 120. Wiley-Liss, Inc. 605 Third Avenue, New York, NY 10518-0012.
- 18 - Ibid. (pp. 148-49).
- 19 - Baumann, Marty. *USA Today*. Feb 2, 1994, p. 1A, 4A. *USA Today* (Gannet Co. Inc.) 1000 Wilson Blvd., Arlington, VA 22229.
- 20 - "The Peril of Chlorine." *Audubon Magazine*, 93:30-2. Nov/Dec 1991.
- 21 - Liptak, B.G. (1991). *Municipal Waste Disposal in the 1990's*. Chilton Book Co.: Radnor, PA. (pp.196-8).
- 22 - Bitton, Gabriel (1994). *Wastewater Microbiology*. p. 312. Wiley-Liss, Inc. 605 Third Avenue, N. Y., NY 10518-0012.
- 23 - Stiak, J. "The Trouble With Chlorine." *Buzzworm*. Nov/Dec 1992. (p.22).
- 24 - Bitton, Gabriel (1994). *Wastewater Microbiology*. p. 121. Wiley-Liss, Inc. 605 Third Avenue, N. Y., NY 10518-0012.
- 25 - *Environment Reporter*. 7/10/92. (p.767).
- 26 - Bitton, Gabriel (1994). *Wastewater Microbiology*. p. 121. Wiley-Liss, Inc. 605 Third Avenue, N. Y., NY 10518-0012.
- 27 - *Buzzworm*, March/April 1993. (p.17).
- 28 - *Environment Reporter*. 7/10/92. (p.767).
- 29 - Ibid. 4/24/92. (p.2879).
- 30 - Ibid. 8/7/92. (p.1155).
- 31 - Burke, W.K. "A Prophet of Eden." *Buzzworm*. Vol. IV, Number 2, March/April 1992. (pp.18-19).
- 32 - *Environment Reporter*. 8/7/92. (P.1152).
- 33 - Ibid. 5/15/92. (p.319).
- 34 - Bitton, Gabriel (1994). *Wastewater Microbiology*. p. 352. Wiley-Liss, Inc. 605 Third Avenue, N. Y., NY 10518-0012.
- 35 - Ibid. 3/6/92 (p. 2474) and 1/17/92 (p.2145).
- 36 - Ibid. 1/3/92 (p.2109).
- 37 - Ibid. 11/1/91 (p.1657) and 9/27/96 (p. 1212).
- 38 - Hammond, A. et al. (Eds.) (1993). *The 1993 Information Please Environmental Almanac*. Compiled by the World Resources Institute. Houghton Mifflin Co.: New York. (p.41).
- 39 - Purves, D. (1990). "Toxic Sludge." *Nature*. Vol. 346, 8/16/1990 (pp. 617-18).
- 40 - Bitton, Gabriel (1994). *Wastewater Microbiology*. p. 352. Wiley-Liss, Inc. 605 Third Avenue, N. Y., NY 10518-0012.
- 41 - Rybczynski, W. et al. (1982). *Appropriate Technology for Water Supply and Sanitation - Low Cost Technology Options for Sanitation, A State of the Art Review and Annotated Bibliography*. World Bank. (p. 124).
- 42 - Ibid. (p. 125).
- 43 - Sterritt, Robert M. (1988). *Microbiology for Environmental and Public Health Engineers*. P. 160. E. & F. N. Spon Ltd., New York, NY 10001 USA.
- 44 - Fahm, L.A. (1980). *The Waste of Nations*. Allanheld, Osmun & Co.: Montclair, NJ (p.61).
- 45 - Shuval, Hillel I. et al. (1981). *Appropriate Technology for Water Supply and Sanitation - Night Soil Composting*. p.5. International Bank for Reconstruction and Development (World Bank), Washington DC, 20433, USA
- 46 - Bitton, Gabriel (1994). *Wastewater Microbiology*. p. 166, 352. Wiley-Liss, Inc. 605 Third Avenue, New York, NY 10518-0012.
- 47 - Sterritt, Robert M. (1988). *Microbiology for Environmental and Public Health Engineers*. P. 242, 251-2. E. & F. N. Spon Ltd., New York, NY 10001 USA.
- 48 - Radtke, T.M., and Gist, G.L. (1989). "Wastewater Sludge Disposal: Antibiotic Resistant Bacteria May Pose Health Hazard." *Journal of Environmental Health*. Vol 52, No.2, Sept/Oct 1989. (pp.102-5).
- 49 - *Environment Reporter*. 7/10/92. (p.770).
- 50 - *Environment Reporter*. 11/1/91. (p.1653).
- 51 - Ibid. 1/17/92. (p.2154).
- 52 - Damsker, M. (1992). "Sludge Beats Lead." *Organic Gardening*. Feb, 1992, Vol. 39, Issue 2, p.19.
- 53 - Contact JCH Environmental Engineering, Inc., 2730 Remington Court, Missoula, MT 59801. Ph: 406-721-1164.
- 54 - Miller, T. L. et al. (1992). *Selected Metal and Pesticide Content of Raw and Mature Compost Samples from Eleven Illinois Facilities*. Illinois Department of Energy and Natural Resources. and: Manios, T. and Stentiford, E.I. (1998). *Heavy Metals Fractionation Before, During, and After Composting of Urban Organic Residues*. As seen in the 1997 Organic Recovery and Biological Treatment Proceedings, Stentiford, E.I. (ed.). International Conference, Harrogate, United Kingdom. 3-5 September, 1997. p. 227-232.
- 55 - US EPA, (1989) - Summary Report: In-Vessel Composting of Municipal Wastewater Sludge. pp. 20, 161. EPA/625/8-89/016. Center for Environmental Research Information, Cincinnati, OH.
- 56 - Fahm. (1980). *The Waste of Nations*. (p.xxiv).
- 57 - Ibid. (p.40).
- 58 - Shuval, Hillel I. et al. (1981). *Appropriate Technology for Water Supply and Sanitation - Night Soil Composting*. (summary). International Bank for Reconstruction and Development (World Bank), Washington DC, 20433, USA.
- 59 - Rivard, C.J. et al. (1989). "Waste to Energy." *Journal of Environmental Health*. Vol 52, No.2, Sept/Oct 1989. (p.100).

60 - See *Garbage*, Oct/Nov 1992, (p.14).

#### REFERENCES — CHAPTER SIX — COMPOSTING TOILETS & SYSTEMS

- 1 - Rybczynski, W. et al. (1982). *Appropriate Technology for Water Supply and Sanitation - Low Cost Technology Options for Sanitation, A State of the Art Review and Annotated Bibliography*. World Bank. Transportation and Water Department, 1818 H Street N.W., Washington D.C. 20433 USA.
- 2 - Franceys et al. (1992). *A Guide to the Development of On-Site Sanitation*. W.H.O., Geneva. (p. 213).
- 3 - McGarry, Michael G. and Stainforth, Jill (eds.) (1978). *Compost, Fertilizer, and Biogas Production from Human and Farm Wastes in the People's Republic of China*. International Development Research Center, Box 8500, Ottawa, Canada, K1G 3H9 (pages 9, 10, 29, 32).
- 4 - Rybczynski, W. et al. (1982). *Appropriate Technology for Water Supply and Sanitation - Low Cost Technology Options for Sanitation, A State of the Art Review and Annotated Bibliography*. World Bank. Transportation and Water Department, 1818 H Street N.W., Washington D.C. 20433 USA. (p. 114).
- 5 - McGarry, Michael G. and Stainforth, Jill (eds.) (1978). *Compost, Fertilizer, and Biogas Production from Human and Farm Wastes in the People's Republic of China*. International Development Research Center, Box 8500, Ottawa, Canada, K1G 3H9.
- 6 - Winblad, Uno, and Kilama, Wen (1985). *Sanitation Without Water*. Macmillan Education Ltd., London and Basingstoke, pp. 20-21.
- 7 - Winblad, Uno (Ed.) (1998). *Ecological Sanitation*. Swedish International Development Cooperation Agency, Stockholm, Sweden. p. 25.
- 8 - Rybczynski, W. et al. (1982). *Appropriate Technology for Water Supply and Sanitation - Low Cost Technology Options for Sanitation, A State of the Art Review and Annotated Bibliography*. World Bank. Transportation and Water Department, 1818 H Street N.W., Washington D.C. 20433 USA.
- 9 - Ibid.
- 10 - Clivus Multrum Maintenance Manual, Clivus Multrum, Inc., 21 Canal St., Lawrence, Mass. 01840. (Also contact Hanson Assoc., Lewis Mill, Jefferson, MD 21755).
- 11 - Ibid.
- 12 - Ibid.
- 13 - Source: Pickford, John (1995). *Low-Cost Sanitation*. Intermediate Technology Publications, 103-105 Southampton Row, London WC1B 4HH, UK. p. 68.
- 14 - Sun Mar Corp., 900 Hertel Ave., Buffalo, NY 14216 USA; or 5035 North Service Road, Burlington, Ontario, Canada L7L 5V2.
- 15 - AlasCan, Inc., 3400 International Way, Fairbanks, Alaska 99701, phone/fax (907) 452-5257 [as seen in *Garbage*, Feb/Mar 1993, p.35].
- 16 - Composting Toilet Systems, PO Box 1928 (or 1211 Bergen Rd.), Newport, WA 99156, phone: (509) 447-3708; Fax: (509) 447-3753.

#### REFERENCES — CHAPTER SEVEN — WORMS AND DISEASE

- AA - Solomon, Ethan B., et. al (2002). *Transmission of Escherichia coli O157:H7 from Contaminated Manure and Irrigation Water to Lettuce Plant Tissue and Its Subsequent Internalization*. Applied and Environmental Microbiology, January 2002, p. 397-400. American Society for Microbiology.
- 1 - Kristof, Nicholas D. (1995). *Japanese is Too Polite for Words*. Pittsburgh Post Gazette, Sunday, September 24, 1995. P. B-8.
- 2 - Beeby, John (1995). *The Tao of Pooh* (now titled *Future Fertility*). Disclaimer, and pp. 64-65. Ecology Action of the Midpeninsula, 5798 Ridgewood Road, Willits, CA 95490-9730.
- 3 - Beeby, John (1995). *The Tao of Pooh* (now titled *Future Fertility*). Pp. 11-12. Ecology Action of the Midpeninsula, 5798 Ridgewood Road, Willits, CA 95490-9730.
- 4 - Barlow, Ronald S. (1992). *The Vanishing American Outhouse*. P. 2. Windmill Publishing Co., 2147 Windmill View Road, El Cajon, California 92020 USA.
- 5 - Warren, George M. (1922 - revised 1928). *Sewage and Sewerage of Farm Homes*. US Department of Agriculture, Farmer's Bulletin No. 1227. As seen in: Barlow, Ronald S. (1992). *The Vanishing American Outhouse*. Pp. 107-110. Windmill Publishing Co., 2147 Windmill View Road, El Cajon, California 92020 USA.
- 6 - Shuval, Hillel I. et al. (1981). *Appropriate Technology for Water Supply and Sanitation - Night Soil Composting*. p.8. International Bank for Reconstruction and Development (World Bank), Washington DC, 20433, USA.
- 7 - Tompkins, P., and Boyd, C. (1989). *Secrets of the Soil*. Harper and Row: New York. (pp.94-5).
- 8 - Howard, Sir Albert. *The Soil and Health: A Study of Organic Agriculture*. Schocken: N. Y. 1947. (pp. 37-38).
- 9 - Ibid. (p.177).
- 10 - Feachem, et al. (1980). *Appropriate Technology for Water Supply and Sanitation*. The World Bank, Director of Information and Public Affairs, Washington D.C. 20433.
- 11 - Sterritt, Robert M. (1988). *Microbiology for Environmental and Public Health Engineers*. P. 238. E. & F. N. Spon Ltd., New York, NY 10001 USA.
- 12 - Jervis, N. "Waste Not, Want Not". *Natural History*. May, 1990 (p.73).
- 13 - Winblad, Uno (Ed.) (1998). *Ecological Sanitation*. Swedish International Development Cooperation Agency, Stockholm, Sweden. p. 75.
- 14 - Sterritt, Robert M. (1988). *Microbiology for Environmental and Public Health Engineers*. Pp. 59-60. E. & F. N. Spon Ltd., New York, NY 10001 USA.
- 15 - Palmisano, Anna C. and Barlaz, Morton A. (Eds.) (1996). *Microbiology of Solid Waste*. Pp. 159. CRC Press, Inc., 2000 Corporate Blvd., N.W., Boca Raton, FL 33431 USA.
- 16 - Gotaas, Harold B., (1956). *Composting - Sanitary Disposal and Reclamation of Organic Wastes*. p.20. World Health Organization, Monograph Series Number 31. Geneva.
- 17 - Sopper, W.E. and Kardos, L.T. (Eds.). (1973). *Recycling Treated Municipal Wastewater and Sludge Through Forest and Cropland*. The Pennsylvania State University, University Park, PA (pp. 248-51).
- 18 - Ibid. (pp. 251-252).
- 19 - Shuval, Hillel I. et al. (1981). *Appropriate Technology for Water Supply and Sanitation - Night Soil Composting*. p.4.

- International Bank for Reconstruction and Development (World Bank), Washington DC, 20433, USA.
- 20 - Sterritt, Robert M. (1988). *Microbiology for Environmental and Public Health Engineers*. P. 252. E. & F. N. Spon Ltd., New York, NY 10001 USA.
- 21 - Cheng, Thomas C. (1973). *General Parasitology*. Academic Press, Inc., 111 Fifth Avenue, N.Y., NY 10003 (p. 645).
- 22 - Shuval, Hillel I. et al. (1981). *Appropriate Technology for Water Supply and Sanitation - Night Soil Composting*. p.6. International Bank for Reconstruction and Development (World Bank), Washington DC, 20433, USA.
- 23 - Feachem et al. (1980). *Appropriate Technology for Water Supply and Sanitation: Health Aspects of Excreta and Sullage Management*. Energy, Water and Telecommunications Department of the World Bank, 1818 H Street N.W., Washington D.C. 20433. This comprehensive work cites 394 references from throughout the world, and was carried out as part of the World Bank's research project on appropriate technology for water supply and sanitation.
- 24 - Ibid.
- 25 - Olson, O. W. (1974). *Animal Parasites - Their Life Cycles and Ecology*. University Park Press, Baltimore, MD (p. 451-452).
- 26 - Crook, James (1985). "Water Reuse in California." *Journal of the American Waterworks Association*, v77, no. 7. as seen in *The Water Encyclopedia* by van der Leeden et al. (1990), Lewis Publishers, Chelsea, Mich. 48118.
- 27 - Boyd, R. F. and Hoerl, B. G. (1977). *Basic Medical Microbiology*. Little, Brown and Co., Boston Mass. (p. 494).
- 28 - Cheng, Thomas C. (1973) *General Parasitology*. Academic Press Inc., 111 Fifth Ave., New York, NY 10003. (p. 645).
- 29 - Sterritt, Robert M. (1988). *Microbiology for Environmental and Public Health Engineers*. Pp. 244-245. E. & F. N. Spon Ltd., New York, NY 10001 USA.
- 30 - Epstein, Elliot (1998). "Pathogenic Health Aspects of Land Application." *Biocycle*, September 1998, p.64. The JG Press, Inc., 419 State Avenue, Emmaus, PA 18049.
- 31 - Shuval, Hillel I. et al. (1981). *Appropriate Technology for Water Supply and Sanitation - Night Soil Composting*. p.5. International Bank for Reconstruction and Development (World Bank), Washington DC, 20433, USA.
- 32 - Franceys, R. et al. (1992). *A Guide to the Development of On-Site Sanitation*. World Health Organization, Geneva. p. 212.
- 33 - Schoenfeld, M., and Bennett, M. (1992). *Water Quality Analysis of Wolf Creek*. (Unpublished manuscript). Slippery Rock University, Applied Ecology Course, PREE, Fall Semester. (Prof. P. Johnson), Slippery Rock, PA 16057
- 34 - Pomeranz, V.E. and Schultz, D., (1972). *The Mother's and Father's Medical Encyclopedia*. The New American Library, Inc., 1633 Broadway, New York, NY 10019. (p.627).
- 35 - Chandler, A.C. and Read, C.P. (1961). *Introduction to Parasitology*. John Wiley and Sons, Inc.: New York.
- 36 - Brown, H.W. and Neva, F.A. (1983). *Basic Clinical Parasitology*. Appleton-Century-Crofts/Norwalk, Connecticut 06855. (pp.128-31). Pinworm destruction by composting mentioned in: Gotas, Harold B., (1956). *Composting - Sanitary Disposal and Reclamation of Organic Wastes*. p.20. World Health Organization, Monograph Series Number 31. Geneva.
- 37 - Brown, H.W. and Neva, F.A. (1983). *Basic Clinical Parasitology*. Appleton-Century-Crofts/Norwalk, Connecticut 06855. (pp.119-126).
- 38 - Ibid.
- 39 - Ibid.
- 40 - Haug, Roger T. (1993). *The Practical Handbook of Compost Engineering*. p. 141. CRC Press, Inc., 2000 Corporate Blvd. N.W., Boca Raton, FL 33431 USA.
- 41 - Shuval, Hillel I. et al. (1981). *Appropriate Technology for Water Supply and Sanitation - Night Soil Composting*. p.4. International Bank for Reconstruction and Development (World Bank), Washington DC, 20433, USA.
- 42 - Franceys, R. et al. (1992). *A Guide to the Development of On-Site Sanitation*. W.H.O., Geneva. p. 214.
- 43 - Shuval, Hillel I. et al. (1981). *Appropriate Technology for Water Supply and Sanitation - Night Soil Composting*. p.7. International Bank for Reconstruction and Development (World Bank), Washington DC, 20433, USA.

#### REFERENCES — CHAPTER EIGHT — THE TAO OF COMPOST

- 1 - LaMotte Chemical Products Co., Chestertown, MD 21620
- 2 - Rodale, J. I., (1960). *The Complete Book of Composting*. P. 650, Rodale Books, Emmaus, PA.
- 3 - Kitto, Dick. (1988). *Composting: The Organic Natural Way*. Thorsons Publishers Ltd.: Wellingborough, UK. (p. 103).
- 4 - World of Composting Toilets Forum Update No. 3, Monday, November 2, 1998.
- 5 - Del Porto, David, and Steinfeld, Carol (1999). *The Composting Toilet System Book* - editor's draft. Center for Ecological Pollution Prevention, PO Box 1330, Concord, MA 01742-1330.
- 6 - Olexa, M. T. and Trudeau, Rebecca L., (1994). *How is the Use of Compost Regulated?* University of Florida, Florida Cooperative Extension Service, Document No. SS-FRE-19, September 1994.
- 7 - Pennsylvania Solid Waste Management Act, Title 35, Chapter 29A.
- 8 - Pennsylvania Municipal Waste Planning, Recycling and Waste Reduction Act (1988), Title 53, Chapter 17A.
- 9 - King, F.H. (1911). *Farmers of Forty Centuries*. Rodale Press, Inc., Emmaus, PA 18049. (pp.78, 202).

#### REFERENCES — CHAPTER NINE — GRAYWATER SYSTEMS

- 1 - Waterless Toilets as Repair for Failed Septic Tank Systems. Bio-Sun Systems, Inc., RR #2, Box 134A, Millerton, PA 16936. Ph: 717-537-2200. Email:Bio-sun@ix.netcom.com
- 2 - US EPA (1992). Wastewater Treatment/Disposal for Small Communities. P. 42. EPA/625/R-92/005. US EPA Office of Research and Development, Office of Water, Washington DC 20460 USA.
- 3 - Bennett, Dick (1995). *Graywater, An Option for Household Water Reuse*. Home Energy Magazine, July/August, 1995.
- 4 - Karpiscak, Martin M. et al. (1990). *Residential Water Conservation: Casa del Agua*. Water Resources Bulletin, December 1990, p. 945-946. American Water Resources Association.
- 5 - Gerba, Charles P. et al. (1995). *Water Quality Study of Graywater Treatment Systems*. Water Resources Bulletin, February, 1995, Vol. 31, No. 1, p. 109. American Water Resources Association.
- 6 - Rose, Joan B. et al. (1991). *Microbial Quality and Persistence of Enteric Pathogens in Graywater from Various Household Sources*. Water Resources, Vol. 25, No. 1, pp. 37-42, 1991.

- 7 - Gerba, Charles P. et al. (1995). *Water Quality Study of Graywater Treatment Systems*. Water Resources Bulletin, February, 1995, Vol. 31, No. 1, p. 109. American Water Resources Association.
- 8 - Karpiscak, Martin M. et al. (1990). *Residential Water Conservation: Casa del Agua*. Water Resources Bulletin, December 1990, p. 940. American Water Resources Association.
- 9 - Rose, Joan B. et al. (1991). *Microbial Quality and Persistence of Enteric Pathogens in Graywater from Various Household Sources*. Water Resources, Vol. 25, No. 1, p. 40, 1991.
- 10 - Karpiscak, Martin M. et al. (1990). *Residential Water Conservation: Casa del Agua*. Water Resources Bulletin, December 1990, p. 940. American Water Resources Association.
- 11 - Ludwig, Art (1994). *Create an Oasis with Greywater*. Oasis Design, 5 San Marcos Trout Club, Santa Barbara, CA 93105-9726. Phone: 805-967-9956.
- 12 - Bennett, Dick (1995). *Graywater, An Option for Household Water Reuse*. Home Energy Mag., July/August, 1995.
- 13 - Rose, Joan B. et al. (1991). *Microbial Quality and Persistence of Enteric Pathogens in Graywater from Various Household Sources*. Water Resources, Vol. 25, No. 1, p. 40, 1991.
- 14 - Rose, Joan B. et al. (1991). *Microbial Quality and Persistence of Enteric Pathogens in Graywater from Various Household Sources*. Water Resources, Vol. 25, No. 1, pp. 37-38, 1991.
- 15 - Rose, Joan B. et al. (1991). *Microbial Quality and Persistence of Enteric Pathogens in Graywater from Various Household Sources*. Water Resources, Vol. 25, No. 1, pp. 39, 41, 1991.
- 16 - Bastian, Robert K. (date unknown). Needs and Problems in Sewage Treatment and Effluent Disposal Facing Small Communities; The Role of Wetland Treatment Alternatives. US EPA, Office of Municipal Pollution Control, Washington DC 20460.
- 17 - Hoang, Tawni et al. (1998). Greenhouse Wastewater Treatment with Constructed Wetlands. Greenhouse Product News, August 1998, p.33.
- 18 - Golueke, Clarence G. (1977). *Using Plants for Wastewater Treatment*. Compost Science, Sept./Oct. 1977, p. 18.
- 19 - Bergthane, R.D. et al. (date unknown). "Green" Water Treatment for the Green Industries: Opportunities for Biofiltration of Greenhouse and Nursery Irrigation Water and Runoff with Constructed Wetlands. and: Gupta, G.C. (1980). *Use of Water Hyacinths in Wastewater Treatment*. Journal of Environmental Health, 43(2):80-82. and: Joseph, J. (1978). *Hyacinths for Wastewater Treatment*. Reeves Journal, 56(2):34-36.
- 20 - Hillman, W.S. and Culley, D.D. Jr. (1978). *The Uses of Duckweed*. American Scientist, 66:442-451.
- 21 - Pries, John (date unknown, but 1996 or later). *Constructed Treatment Wetland Systems in Canada*. Gore and Storrie Ltd., Suite 600, 180 King St. S., Waterloo, Ontario, N2J 1P8. Ph: 519-579-3500.
- 22 - Golueke, Clarence G. (1977). *Using Plants for Wastewater Treatment*. Compost Science, Sept./Oct. 1977, p. 18.
- 23 - Golueke, Clarence G. (1977). *Using Plants for Wastewater Treatment*. Compost Science, Sept./Oct. 1977, p. 17.
- 24 - For more information, contact Carl Lindstrom at [www.greywater.com](http://www.greywater.com).
- 25 - Gunther, Folke (1999). *Wastewater Treatment by Graywater Separation: Outline for a Biologically Based Graywater Purification Plant in Sweden*. Department of Systems Ecology, Stockholm University, S-106 91, Stockholm, Sweden. Ecological Engineering 15 (2000) 139-146.

#### REFERENCES — CHAPTER TEN — THE END IS NEAR

- 1 - Rybczynski, W. et. al. (1982). *Appropriate Technology for Water Supply and Sanitation - Low Cost Technology Options for Sanitation*. A State of the Art Review and Annotated Bibliography. World Bank, Geneva. (p. 20).
- 2 - Kugler, R. et al. (1998). *Technological Quality Guarantees for H.Q. Compost from Bio-Waste*. As seen in the 1997 Organic Recovery and Biological Treatment Proceedings, Stentiford, E.I. (ed.). International Conference, Harrogate, United Kingdom. 3-5 September, 1997. P. 31. Available from Stuart Brown, National Compost Development Association, PO Box 4, Grassington, North Yorkshire, BD23 5UR UK ([stuartbrown@compuserve.com](mailto:stuartbrown@compuserve.com)).
- 3 - Vorkamp, Katrin et al. (1998). *Multiresidue Analysis of Pesticides and their Metabolites in Biological Waste*. As seen in the 1997 Organic Recovery and Biological Treatment Proceedings, Stentiford, E.I. (ed.). International Conference, Harrogate, United Kingdom. 3-5 September, 1997. p. 221. Available from Stuart Brown, National Compost Development Association, PO Box 4, Grassington, North Yorkshire, BD23 5UR UK ([stuartbrown@compuserve.com](mailto:stuartbrown@compuserve.com)).
- 4 - Wheeler, Pat (1998). *Results of the Environment Agency Research Programme into Composting of Green and Household Wastes*. As seen in the 1997 Organic Recovery and Biological Treatment Proceedings, Stentiford, E.I. (ed.). International Conference, Harrogate, United Kingdom. 3-5 September, 1997. p. 77. Available from Stuart Brown, National Compost Development Association, PO Box 4, Grassington, North Yorkshire, BD23 5UR UK ([stuartbrown@compuserve.com](mailto:stuartbrown@compuserve.com)).
- 5 - Johnson, Julie. (1990). "Waste That No One Wants." *New Scientist*. 9/8/90, Vol. 127, Issue 1733. (p.50).
- 6 - Benedict, Arthur H. et. al. (1988). "Composting Municipal Sludge: A Technology Evaluation." Appendix A. Noyes Data Corporation.
- 7 - Biocycle, January 1998, p. 71.
- 8 - <http://www.epa.gov/compost/basic.htm>
- 9 - Johnson, Julie. (1990). *Waste That No One Wants*. (p. 53) see above.
- 10 - Simon, Ruth. (1990). *The Whole Earth Compost Pile?* Forbes. 5/28/90, Vol. 145, Issue 11, p. 136.
- 11 - Biosolids Generation, Use and Disposal in the United States (1999). EPA 630-R-99-009.
- 12 - Gotaas, Harold B., (1956). *Composting - Sanitary Disposal and Reclamation of Organic Wastes*. p.101. World Health Organization, Monograph Series Number 31. Geneva.

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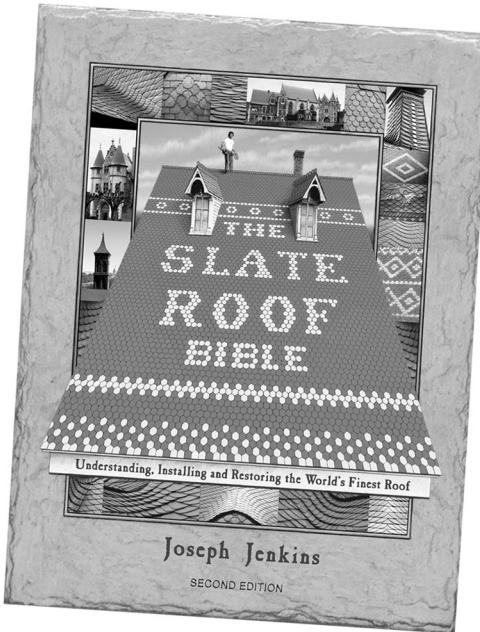
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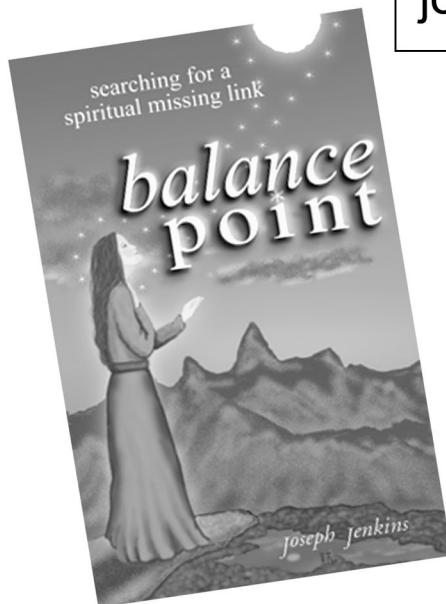
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