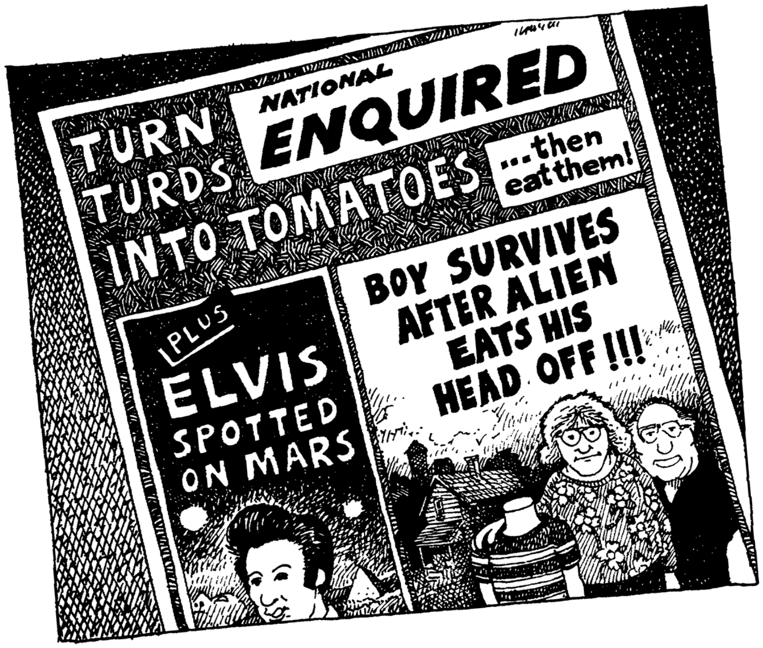


Chapter Ten

Compost Miracles

Compost microorganisms not only convert organic material into compost and eliminate disease organisms in the process, but they also degrade toxic chemicals into simpler, benign, organic molecules. These chemicals include gasoline, diesel fuel, jet fuel, oil, grease, wood preservatives, polychlorinated biphenyls (PCBs), coal gasification wastes, refinery wastes, insecticides, herbicides, TNT, and other explosives.[1]

In one research study, when compost piles were laced with insecticides and herbicides, the insecticide (carbofuran) was completely degraded, and the herbicide (triazine) was 98.6 percent degraded after fifty days of composting. In another, when soil contaminated with diesel fuel and gasoline was composted for seventy days, the total petroleum hydrocarbons were reduced approximately 93 percent.[2] Soil contaminated with dicamba herbicide at a level of three thousand parts per million showed no detectable levels of this toxic contaminant after only fifty days of composting. In the absence of composting, the biodegradation process takes years.

Fungi in compost produce a substance that breaks down petroleum, thereby making it available as food for bacteria.[3] 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.[4] 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.[5]

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 twenty-five months, the chlorophenol was reduced in concentration by over 98 percent. In other compost trials Freon contamination was reduced by 94 percent, PCBs by up to 98 percent, and trichloroethylene by 89 to 99 percent.[6] Some of this degradation is due to the efforts of fungi at lower (mesophilic) temperatures.[7]

Some bacteria even have an appetite for uranium. 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.[8]

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 that contaminated his and his neighbor's fields. Sigfried Lubke sprayed his green manure crops with compost-type microorganisms just before plowing them under. This practice 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 because of 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.[9]

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 prior method of choice for eliminating contaminated soil has 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 fifteen thousand tons of contaminated soil instead of incinerating it, it saved approximately $2.6 million. Although the Umatilla soil was heavily contaminated with TNT and Royal Demolition Explosives, no explosives could be detected after composting and the soil was restored to "a better condition than before it was contaminated."[10] Similar results have been obtained at Seymour Johnson Air Force Base in North Carolina; the Louisiana Army Ammunition Plant; the US Naval Submarine Base in Bangor, Washington; Fort Riley in Kansas; and the Hawthorne Army Depot in Nevada.[11]

The US Army Corps of Engineers estimates that taxpayers would save hundreds of millions of dollars if composting, instead of incineration, were used to clean up the remaining US munitions sites. The ability of compost to bioremediate toxic chemicals is particularly meaningful when one considers that in the US there are thousands of Department of Defense sites in need of remediation.

Some success has been shown in the bioremediation of PCBs in composting trials conducted by Michigan State University researchers. In the best case, PCB loss was in the 40 percent range. Despite the chlorinated nature of the PCBs, researchers still managed to get quite a few microorganisms to choke the stuff down.[12]

As promising as compost bioremediation appears, however, it can-not heal all wounds. Heavily chlorinated chemicals show considerable resistance to microbiological biodegradability. Apparently, there are some things even a fungus will spit out.[13] For example, there's the villain Clopyralid (3,6-dichloropicolinic acid), a "persistent herbicide" manufactured by Dow AgroSciences that contaminated vast amounts of commercial compost in the early twenty-first century. Clopyralid has a few cousins, including: Aminopyralid (Dow AgroSciences), Aminocyclopyrachlor (DuPont), and Picloram (Dow AgroSciences). These persistent herbicides are mostly unaltered during microbial digestion, and in fact microbes can concentrate these chemicals because, to them, they are a waste material. Plants suffering from these pesticide residues in compost show stunted growth, reduced fruit set, cupping of leaves, and so on. Sensitive plant families include peas, beans, lentils, clover, tomatoes, potatoes, sunflowers, petunias, daisies, lettuce, asters, cucumbers, squash, pumpkin, and watermelon. Persistent herbicides can last anywhere from several months to three or more years before completely breaking down. If you wonder why some compost operations won't take grass clippings from golf courses, or even cow manure, now you know. Even a compost pile can have a bad day.[14]

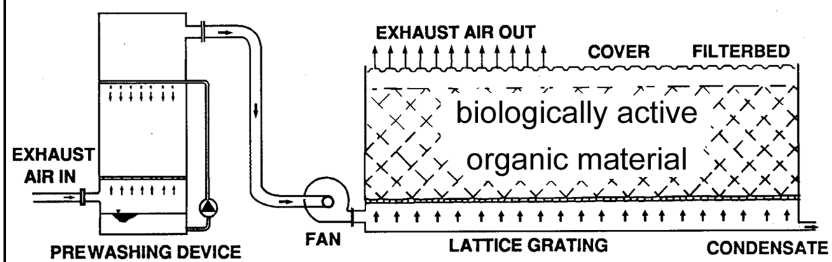
Compost Filters Pollutants

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 exhaust air is drawn to remove any contaminants. The microorganisms in the organic material eat the contaminants and convert them into carbon dioxide and water.

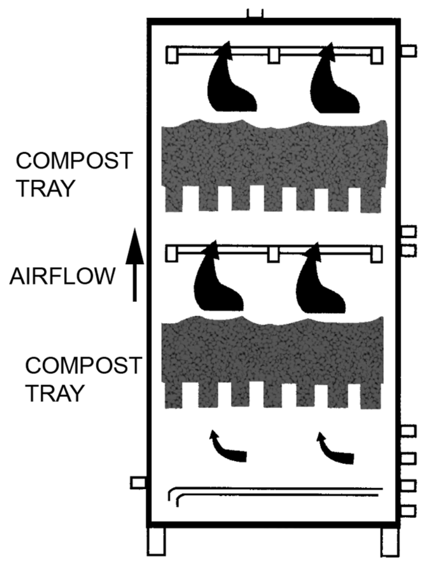
Sawdust and other finely ground carbon-based organic materials also make excellent biofilters in compost toilets. "Cover materials," as they are called, are used to cover the contents of the toilets; some work so well the toilets can be located indoors, even next to a bed.

In Rockland County, New York, a commercial composting biofil-

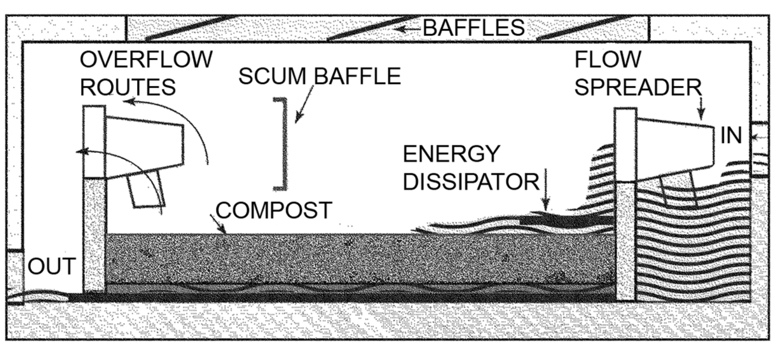
BIOFILTERS



VAPOR PHASE
COMPOST
BIOFILTER



COMPOST STORMWATER BIOFILTER



Source: US EPA

tration system can process eighty-two thousand 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 eighteen months. Vapor phase biofilters can maintain a consistent volatile organic compound removal efficiency of 99.6 percent, which isn't bad for a bunch of microorganisms.[15] 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 used to filter stormwater runoff. Compost stormwater filters use compost to filter out heavy metals, oil, grease, pesticides, sediment, and fertilizers from stormwater. Such filters can remove over 90 percent of all solids, 82 to 98 percent of heavy metals and 85 percent 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.[16]

Compost Defends Against Plant Diseases

Compost microbes directly compete with, inhibit, or kill organisms that cause diseases in plants. Because of this, diseased plant material should be composted rather than returned to the land, where reinoculation of the disease could occur. Plant pathogens are also eaten by micro-arthropods, such as mites and springtails, which are often found in compost.[17] Compost microorganisms can also produce antibiotics that suppress plant diseases.

Compost added to soil can 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.[18] 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,[19] *Fusarium oxysporum* in potted plants, and gummy stem blight and damping-off diseases in squash.[20] 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 greenhouse soils. He and a team of scientists took out a patent for compost that could reduce or suppress plant diseases caused by three deadly microorganisms: *Phytophtora*, *Pythium,* and *Fusarium*. Growers who used this compost in their planting soil reduced their crop losses to 1 percent from a range of 25 to 75 percent 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.[21]

Compost tea has also been demonstrated to have disease-reducing properties in plants. The tea is made by soaking semi-mature compost in water for three to twelve days, then filtering and spraying it on plants, coating the leaves with live bacteria colonies. When sprayed on red pine seedlings, for example, blight was significantly reduced in severity.[22] Powdery mildew (*Uncinula necator*) on grapes was suppressed by compost tea made from cattle manure compost.[23] "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." [24]

When scientists inoculated wood chips with three different fungal plant pathogens, then composted them, they found that a temperature of 104°F (40°C), when exceeded for more than five days, was sufficient to kill all three of the organisms.[25] *Fusarium*, a pathogenic fungus that blights cereal crops, was composted by other researchers. They found that *Fusarium* species were rapidly eradicated from infected grains in windrow compost. When temperatures achieved 124°F (51°C), the pathogens were eliminated in only two days. At lower temperatures it could take up to twenty-two days for total elimination.[26]

Besides helping to control soil and plant diseases, compost attracts earthworms, aids plants in producing growth stimulators, and helps control parasitic nematodes.[27] 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.[28] Composting also destroys weed seeds. Researchers observed that after three days in compost at 131°F (55°C), all the seeds of the eight weed species studied were dead.[29]

Compost Recycles 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 US each year, about 37 million die from disease and other natural causes before they're marketed.[30] The dead birds can simply be composted. The composting process not only converts the carcasses to compost that 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 131°F (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. 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. Carcass composting can be accomplished without odors, flies, or scavenging birds or animals.

Animal carcasses that are now composted include full-grown pigs, cattle, horses, fish, sheep, calves, and other animals. The process of composting dead animals is the same as composting any other organic material. The carcasses provide nitrogen and moisture, while sawdust, straw, corn stalks, and paper provide carbon and bulk for air impregnation. The composting can be done in temporary 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 biological 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 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 eventually broken down when applied to the soil.[31] Smaller animals carcasses such as from dogs can be added to the compost with no prior preparation.

When a small animal has died, and the carcass needs to be recycled, simply dig a hole in the top center of your compost pile, deposit the carcass in the hole, cover it with the existing 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.

I keep some ducks and chickens on my homestead, and occasionally one of them dies. A little digging 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. I've also used this technique regularly for recycling other small animal carcasses such as mice, baby chicks, and baby rabbits. After collecting earthworms from my compost pile to go fishing at the local pond, I filet the catch. The fish remains go straight into the compost, buried in the same manner as any other animal mortality. My most recent backyard household compost bin (2018) contained twenty-nine animal mortalities, mostly raccoons and opossums, but also the chickens and ducks these predators killed. Covering the carcasses with toilet material from the compost toilet really blocked the odor. When you're throwing four thirty-pound dead raccoons into your compost bin at once, the smell can be horrific if the contents of the bin aren't adequately covered. Always bury the carcass *inside* the pile, cover it with toilet material or food scraps to accelerate the decomposition, rake the existing compost over it, then add a heavy layer of straw or other clean cover material on top. Still smell something? Add more cover material until you don't. Let your nose be your guide. Of course, these are contained piles that are *never* turned. You do not want to be turning compost piles full of humanure and dead animals. This composting technique is explained in the *Tao of Compost* chapter.

My outdoor cats wouldn't be caught dead digging around in compost looking for a bite to eat. Nor would my dog — and dogs will eat just about anything — but not when buried in a properly managed compost pile. In the forty-two years I've lived at my homestead, bears have become increasingly common. They've ransacked the neighborhood garbage cans many times, raided the bird feeders in my garden, knocked over my bee hives, been on my porch, and clawed my screen door, but they have never shown any interest in any of my compost piles.

Nevertheless, make sure your compost bin has animal-proof sidewalls, and then simply lay a piece of stiff wire fencing on top of the compost. That's all it takes. Until animals learn how to use wire cutters, your compost will be safe.

Compost Recycles Pet Manures

A lady asked me if you can compost a dog turd. I told her I can compost an entire dog, so why wouldn't a dog turd compost as well? When our full-size family collie died a few years ago of old age, in the middle of the winter, her frozen carcass had a proper burial in the bottom of a compost bin. A year later all that was left was a bare skull and a little bit of fur. All that compost went into one of my flower beds, where, when the flowers bloom, I often think of the dog, Sylvie.

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 phosphorus if the dogs are fed with proper care and given their share of bones." According to *BioCycle* (October 2016), San Francisco alone has 120,000 dogs that produce thirty-two million pounds of dog manure annually. Compost microbes will eat it all.

Compost Even Recycles Junk Mail

Composting is a solution for junk mail, too. A pilot composting project was started in Dallas-Ft. Worth, Texas, where eight hundred 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. All of it 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.[32]

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 and heavy metals 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 that may be 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.[33]

Woods End Laboratory in Maine did some research on composting ground-up telephone books and newsprint that 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 percent.[34] 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 most of the toxic elements from the newsprint. It'll probably make acceptable compost, too, especially if composted with garbage, manure, and other organic materials.

Pharmaceuticals in Compost

With the American epidemic of both antibiotic and pharmaceutical usage, a thinking person must wonder, what happens to all those drugs after they're ingested and excreted? What about the drugs people buy but don't use and instead discard? What about pharmaceuticals in your compost? Does composting even break down the drugs? Are some pharmaceuticals worse than others? Do plants take up pharmaceuticals? These are good questions, and there are a lot of issues at play here.

For a sense of scale, Alameda County's drug disposal program in California alone brings in an incredible seven tons of prescription drugs a year, which must be shipped out of the state to be incinerated.[35] At least they don't end up down the toilet and in the water.

To get answers, scientists and researchers must take antibiotics and pharmaceuticals and introduce them into composting environments, then monitor and record the effects on the pharmaceuticals. Unfortunately, no one is doing such research on humanure composting, because, at least in the US, humanure compost is not very available. On the other hand, sewage sludge compost and animal manure composts are available, so we must look at these research studies to get an idea of what composting does to pharmaceuticals and other chemicals that humans and other animals excrete or discard into the environment.

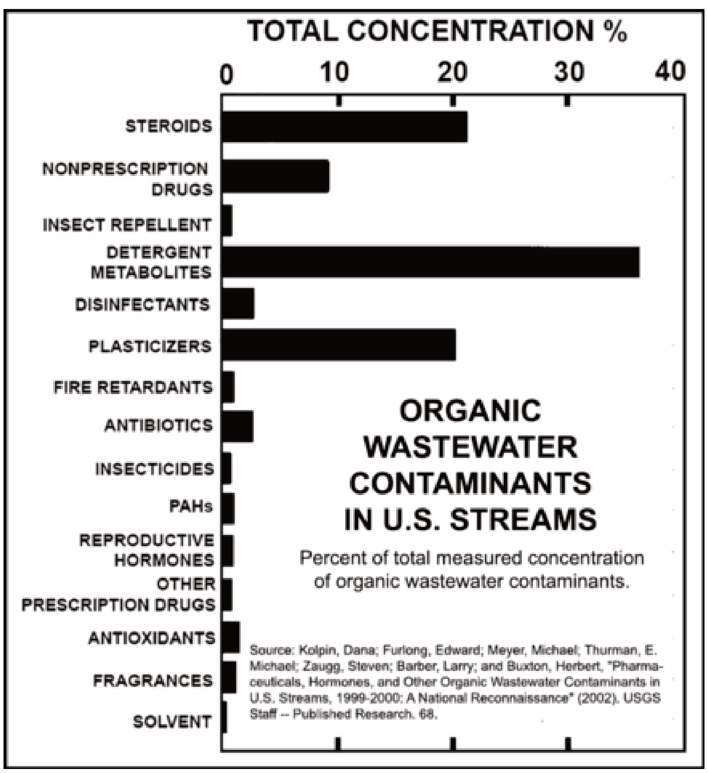
Approximately 170,000 public water systems in the US are monitored for nearly eighty harmful substances, including bacteria, viruses, pesticides, petroleum products, strong acids, and some metals, but water is also polluted by unmonitored chemicals such as pharmaceuticals, perfume, cologne, skin lotions, and sunscreens. Our bodies metabolize only a fraction of the drugs we ingest, while about half of all medications are discarded, often down drains. Most of the remainder is excreted and gets into wastewater via toilets. Hospitals and nursing homes dispose of drugs down their drains too. In addition, the two trillion pounds of animal manures generated by poultry and livestock farms in the US are also contaminated with hormones and antibiotics, which inevitably leach into groundwater or surface waterways.[36]

A study conducted by the US Geological Survey found medications in 80 percent of the water samples from a sampling of 139 streams in thirty states. The drugs included antibiotics, antidepressants, blood thinners, heart medications, hormones, and painkillers. The most frequently detected compounds were steroids, insect repellents, caffeine, triclosan (an antimicrobial disinfectant), fire retardants, and detergent metabolites.[37] Other drugs contaminating our waters include carbamazepine (an antiseizure drug), fibrates (a cholesterol drug), and fragrance chemicals like galaxolide and tonalide. Water purification plants and wastewater treatment plants aren't designed to remove these contaminants. In fact, the chemicals can become concentrated in the sewage sludge produced by the plants.[38]

About half the sewage sludge (biosolids) produced in the USA is applied to land, providing a significant opportunity for contaminants to enter soil systems and to bioaccumulate over time from the repeated application of the sludge. Thirty-five new chemicals and six new microbial pollutants were identified in biosolids in the USEPA's 2013 *Biennial Review* alone, yet data regarding the health effects of these contaminants was non-existent.[39] Sewage sludge is used in large-scale landscaping, home landscaping, gardens, abandoned mining sites, farms, and elsewhere.

For example, fluoroquinolones, antibacterial drugs used for humans and animals, "become highly enriched in sewage sludge." Application of sewage sludge to soils is therefore a potential route for these drugs to enter the environment. Moreover, fluoroquinolones persist in sludge-treated soils up to several months after application.[40]

One study looked at the degradation of three pharmaceuticals: naproxen (anti-inflammatory drug), carbamazepine (anticonvulsant), and fluoxetine (antidepressant) in soils, sludge, and soil-sludge mixtures (but not in compost). The carbamazepine and fluoxetine didn't



degrade, while the naproxen slowly degraded. However, when the antibiotic sulfamethazine was added, the degradation of the naproxen slowed down, indicating that combinations of drugs, or the addition of antibiotics to the contaminant stew, reacts to soil environments differently than do individual drugs. Degradation rates of pharmaceuticals in soils can range from days to years.[41]

Repeated land application of sewage sludge can result in localized concentrations of contaminants. For example, one study indicated that brominated fire retardants were still found at almost eight thousand times higher concentrations than background concentrations in soil samples twenty years after the last application of biosolids. In another study, fifteen out of nineteen pharmaceutical drugs were still present in soil six months after being irrigated with contaminated wastewater.[42]

In the United States, we each produce, on average, about 120 gallons of wastewater daily, containing 3 ounces of organic wastewater solids per person per day, much of which consists of toxic chemicals. In one study, nine varieties of sewage sludge from municipal wastewater treatment plants in seven different states were analyzed for eighty-seven different organic water contaminants, including pharmaceuticals, steroids, hormones, detergents, fragrances, plasticizers, fire retardants, disinfectants, and pesticides. Many of these contaminants exit wastewater treatment plants intact or incompletely removed and thereby end up in the environment. A minimum of 30 and a maximum of forty-five contaminants were detected in any one biosolids sample. The study indicated that the organic contaminants are concentrated in the sludge. These contaminants can cause increased rates of cancer and reproductive impairment in humans and other animals, as well as antibiotic resistance among pathogenic bacteria.[43]

What about composting? Will it remove antibiotics, pharmaceuticals, and organic contaminants? In one study, soil contaminated with the pharmaceuticals probenecid (gout medicine) and methaqualone (a sedative) was composted. These were biologically active compounds, so removal from the soils was important. Results showed that the most effective removal occurred at 77° F (25°C), although the probenecid removal in the thermophilic stage ranged from 75 to 100 percent. Composting "removed the contaminants to the agreed end-points." The compost was subsequently used for landscaping purposes.[44]

Interesting that the mesophilic temperatures were more effective in removing the contaminants, presumably because there is a higher diversity of microorganisms with more "tools" at their disposal. This phenomenon was replicated in a study involving polycyclic aromatic hydrocarbons (PAHs), organic pollutants that are widely distributed in the environment, are frequently detected in soils, and are toxic, even carcinogenic. This study "proved that mesophilic conditions were better performing than thermophilic conditions. The highest removal of three- and four-ring PAHs were observed in reactors displaying mesophilic conditions." On the other hand, the highest removal of five-ring PAHs took place under thermophilic conditions. Composting, in this case, "was considered a high efficiency biostimulation strategy for the degradation of persistent PAHs. . . ."[45]

Approximately thirty million pounds of antibiotics are used annually in the US for agricultural purposes, about 70 percent of which is excreted in manure. One study showed that sulfachlorpyrazine (a poultry drug) decreased by 58 to 82 percent during only eight days of composting. Another experiment showed a 99 percent removal of oxytetracycline (an antibiotic) after thirty-five days of composting, while less than a 15 percent reduction was achieved at room temperature. After thirty-five days of thermophilic temperatures, another antibiotic, chlortetracycline, was reduced more than 99 percent; the antibiotics monensin and tylosin were reduced from 54 to 76 percent, whereas the antibacterial drug sulfamethazine did not degrade at all in this time period.[46] Another study indicated that composting is effective in reducing salinomycin (a broad-spectrum antibiotic) in manure.[47]

From 2001 to 2003 roughly thirty-three hundred tons of tetracycline antibiotics were produced annually for animals in the US. Oxytetracycline is the most widely used tetracycline compound administered. As an environmental contaminant, it can affect algae, crustaceans, and soil bacteria; can create antibiotic-resistant bacteria;

and can risk contamination of the food chain. Approximately 23 percent of the oxytetracycline fed to calves passes through in the manure. Although this antibiotic was present in manure being composted, it did not appear to affect the composting process. Within the first six days of composting, levels of oxytetracycline were reduced 95 percent. The researchers recommended that farmers should be advised of the persistence of oxytetracycline in untreated manure and should compost manure to reduce oxytetracycline residues. In contrast, such residues in manure were not effectively reduced during *anaerobic* digestion.[48]

Other research indicated that aerobic windrow composting of manure would significantly reduce the amount of chlortetracycline (an antibiotic), sulfamethazine (anti-bacterial drug), and tylosin (an antibiotic).[49] Additional research involved three common classes of antibiotics (tetracyclines, sulfonamides, and macrolides). During composting, in both field and lab-scale investigations, the concentrations of all three antibiotics declined to acceptable levels. It's interesting to note that the decline of tetracycline and sulfonamide concentrations was highly dependent on the presence of sawdust while there was no influence of sawdust on the tylosin.[50] Another study investigated three antibiotics, including chlortetracycline, oxytetracycline, and tetracycline in swine manure composting. During the pilot scale composting, they were degraded by 74 percent, 92 percent and 70 percent, respectively.[51]

When byproducts of poppy production were thermophilically composted for fifty-five days to remove morphine, the morphine content decreased below detectable levels after thirty days, even when the windrow compost was not turned at all.[52]

Both male and female human hormones showed an 84 to 90 percent reduction after 139 days of composting in poultry manure. Although the levels of hormones were reduced during composting, they were not completely eliminated during that time period.[53] Perhaps a longer curing phase was needed?

What about residual drugs in animal carcasses? Phenylbutazone (an anti-inflammatory drug) was undetectable after composting. Ivermectin (a deworming agent) had undetectable levels by the end of the composting process. The fate of barbiturates after composting is mixed and requires further research. "Studies are just beginning to reveal the impact of composting on drugs and drug residues…While more research is needed, recent and ongoing studies are supporting the use of composting. . . ."[54]

About 70 percent of the drugs we ingest is excreted. Much of the pharmaceuticals we excrete exits our bodies in our urine. Although urine is easily composted, there is a subset of "dry toilet" users who prefer to segregate urine and use it directly on plants and gardens, diluted beforehand with water. A study in Germany indicated that there are 124 active pharmaceutical agents in the average German urine, which is unbelievable. The study concluded that "it is recommended not to use urine of people under medication for fertilization of food crops."[55] No doubt they mean direct fertilization. Composting urine beforehand would benefit from the same remediation that is achieved when composting contaminated manure, sludge, and soils.

Will edible plants uptake drugs from contaminated soils? A greenhouse experiment studied the uptake of carbamazepine (an anticonvulsant), diphenhydramine (an antihistamine), and fluoxetine (an antidepressant), and two personal care products — triclosan (an antibacterial) and triclocarban (another antibacterial) in the soybean plant. After growing for 60 and 110 days, carbamazepine, triclosan, and triclocarban were found to be concentrated in root tissues and translocated into above ground parts of the plant, including the beans. Accumulation and translocation of the diphenhydramine and fluoxetine was limited. Growth in biosolids resulted in higher plant concentrations, probably due to higher concentrations of contaminants. Contaminants introduced by irrigation were more available for uptake and translocation into the plant tissue.[56]

Another greenhouse study used corn, green onion, and cabbage. All three crops absorbed chlortetracycline (an antibiotic) but not tylosin (another antibiotic). The concentrations of chlortetracycline in plant tissues were small, but the concentrations increased with increasing amount of antibiotics present in the manure. This study points out the potential human health risks associated with consumption of fresh vegetables grown in soil amended with antibiotic laden manures. The risks may be higher for people who are allergic to antibiotics. There is also the possibility of enhanced antimicrobial resistance as a result of human consumption of these crops.[57] Clearly, contaminated manures should be composted rather than used raw in agriculture.

Additional research studies also confirm that pharmaceuticals are absorbed by plants grown in soil fertilized with sewage sludge. "Uptake of ciprofloxacin, norfloxacin, ofloxacin, sulfadimethoxine, and sulfamethoxazole was demonstrated in lettuce. The uptake of fluoroquinolones and sulfonamides by plants such as lettuce does not seem to be a major human health risk, as the detected levels of the studied pharmaceuticals were relatively low, if compared to their soil concentrations."[58] These same antibiotics were studied on wheat, carrots, and potatoes, grown in sewage sludge fertilized soil. The wheat grains had no uptake, but the potatoes and carrots did, enough that the researchers warned that *plants like potato and carrot might present a health risk.*[59]

Then there are the chemotherapy drugs. I couldn't find much research on the effect of composting on these drugs, but there are a lot of warnings about them. These drugs not only directly attack DNA, but they pass through cancer patients as active chemicals in urine, feces, vomit, saliva, and sweat. One of the most powerful and dangerous chemo drugs is cyclophosphamide. Accidental contamination by this drug can cause cancer, birth defects, miscarriages, leukemia, and permanent infertility. Patients can even develop cancers that don't appear for several years. For example, cyclophosphamide, although used to treat breast cancer, can cause bladder cancer. Yet, we routinely flush the excretions of cancer patients down the toilet. Although the American Cancer Society recommends flushing the toilet twice, somehow this doesn't sound very reassuring. The ACS warns that toilets used by cancer patients can be hazardous, as can even the lips of a chemo patient (they recommend no kissing). Chemotherapy drugs can exit cancer patients as active and dangerous chemicals. Septic systems and wastewater treatments plants can't remove 98 percent of them, so they end up intact in lakes, rivers and ponds, and eventually into our drinking water supplies.[60] One anti-cancer drug, salinomycin, was composted in manure. The researchers concluded that "on the basis of the results obtained in this study, it appears that the composting technique is effective in reducing salinomycin in manure." [61]

What do you do if you're on chemotherapy and are also a compost toilet user? I will not hazard a guess, because the jury is still out on that subject. I hope more research will be conducted in which the toxic chemo drugs are subjected to true composting over an extended time period. We can also hope that the medical industry develops treatments for cancer that aren't so threatening and damaging.

Heavy Metals

Here is another frequently asked question regarding compost and compost toilets. "What about the heavy metals?" My answer: What heavy metals? Where are the heavy metals coming from? If you're excreting heavy metals, then you have a serious problem. Otherwise, how would heavy metals get into your compost toilet? It seems that some people hear that heavy metals can contaminate compost; therefore all compost must suffer from heavy metal contamination. No, that's not true at all.

But yes, heavy metals can be a problem for the composting industry, depending on the source of the feedstocks being composted. Some feedstocks are contaminated with heavy metals such as lead, copper, and cadmium, especially "municipal solid waste" feedstocks. Soils can also be contaminated due to the long-term use of sewage for irrigation, extensive use of chemical fertilizers and pesticides, and careless storage of industrial and mining wastes. Your shit, on the other hand, is clean (so to speak). Unless you're eating heavy metals.

Remember that what you put into a compost pile is what the microorganisms want to eat. They don't eat heavy metals. On the other hand, compost can strongly bind metals and prevent their uptake by both plants and animals, thereby preventing transfer of metals from contaminated soil into the food chain.[62] 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.[63] Plants grown in lead-contaminated soil with 10 percent compost showed a reduction in lead uptake of 82.6 percent, compared to plants grown in soil with no compost.[64]

But it's more complicated than this. For example, three composts were tested in a 1997 research study, one made from cattle manure, one from sewage sludge, and one from municipal solid waste. The cattle manure compost had the least heavy metal contamination, the sewage sludge compost contained more zinc, copper, and lead than the manure compost, and the municipal solid waste compost contained the most heavy metals of all three. After six years, the sludge compost "did not cause any significant increase in heavy metal levels in soil and plants." On the other hand, the municipal solid waste compost increased concentrations of zinc, copper, nickel, lead, cadmium, and chromium in the soil, and in the case of lead and cadmium, also in the vegetation and the fruits.[65]

In another experiment, published in 2013, two separate composts (olive pomace compost, and municipal solid waste compost) were applied to soil in a Mediterranean environment. At the end of the first four years, neither of the composts caused any heavy metal accumulation in the soil or the plants.[66]

Studies have found that compost is a promising strategy to immobilize heavy metals in soils by changing the soil properties. Reactions between heavy metals and organic matter in compost can turn the toxic state of heavy metals to a non-toxic state. Compost applied to contaminated agricultural soils can also reduce the bioavailability of heavy metals, thus reducing harm to plants, soil animals, and microorganisms. Compost can also reduce heavy metal contents in water by 85 to 89 percent through chemical absorption.[67]

Although compost usually reduces the available forms of heavy metals to plants, the addition of compost to soils can also *increase* the plant uptake of heavy metals depending on the plant species. Also, the extensive use of compost made from feedstocks contaminated with heavy metals can *increase* the risk of heavy metal pollution in soils. Stable, mature, well cured compost seems to have the greatest effect on binding heavy metals, compared to immature composts. Different metals also react differently to compost; while some may be bound in the soils and kept out of the plant material, thanks to the compost, other metals in the same soil may become more available to the same plants. Plants that tend to accumulate heavy metals can strategically be used to extract the metals from the soils, after which the plants can be disposed of in some manner, effectively reducing the heavy metal contamination in the soil.

It's also interesting to note that earthworms seem to reduce the toxicity of heavy metals in compost.[68] Like I said, it's complicated.

In summary, humanure is not a source of heavy metal pollution, so don’t worry about your compost toilet. Worry about compost made from heavily contaminated source materials such as municipal solid waste, especially if derived from industrial areas. The solution is to source separate discarded materials so trash or effluents containing heavy metals can be quarantined and disposed of or recycled properly. It’s not surprising that heavy metal contamination in waste materials increases as socioeconomic status increases, according to a study conducted in Bangladesh.[69]

Incidentally, the maximum heavy metal contents allowed in Class A+ Compost (for use in organic agriculture) in Europe are as follows (grams per tonne) — lead: 45; cadmium: 0.7; copper: 70; nickel: 25; mercury: 0.4; zinc: 200, and chromium: 70.[70]

Finally, as you read this there may have been dozens if not hundreds of research studies regarding antibiotics and heavy metals in compost since this book was written. I hope this chapter provides a suitable introduction to the information that is currently available.