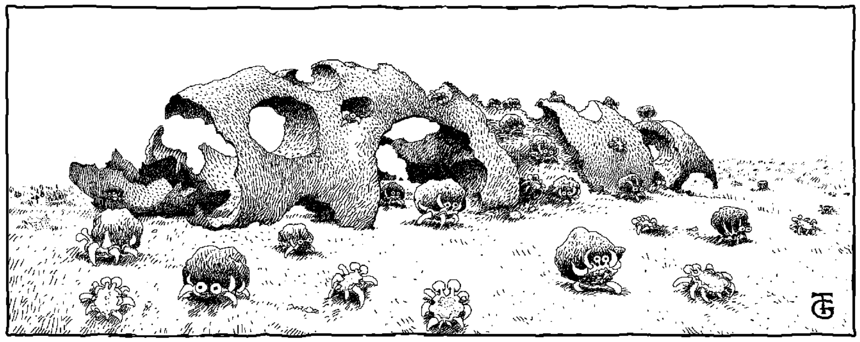


MICROHUSBANDRY

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."* [1] 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."* [2]

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^{0}C or 98.6^{0}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^{0} to 60^{0}C for several hours."* [3] 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."* [4]

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."* [5]

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%.[6]

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 compost are slowly released throughout the growing season, making them less susceptible to loss by leaching than the more soluble chemical fertilizers.[7] 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.[8]

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."* [9]

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.[10] 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%[11]. Even when wet materials are composted, a pile can undergo considerable drying.[12] An initial moisture content of 65% can dwindle down to 20 to 30% in only a week, according to some researchers.[13] 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.[14] 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).[15] 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.[16] 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.[17]

Table 3.2

CARBON/NITROGEN RATIOS

Material	%N	C/N Ratio
Activated Sldg.	5-6	6
Amaranth	3.6	11
Apple Pomace	1.1	13
Blood	10-14	3
Bread	2.10	---
Cabbage	3.6	12
Cardboard	0.10	400-563
Coffee Grnds.	---	20
Cow Manure	2.4	19
Corn Cobs	0.6	56-123
Corn Stalks	0.6-0.8	60-73
Cottonseed Ml.	7.7	7
Cranberry Plant	0.9	61
Farm Manure	2.25	14
Fern	1.15	43
Fish Scrap	10.6	3.6
Fruit	1.4	40
Garbage (Raw)	2.15	15-25
Grass Clippings	2.4	12-19
Hardwood Bark	0.241	223
Hardwoods (Avg)	0.09	560
Hay (General)	2.10	---
Hay (legume)	2.5	16
Hen Manure	8	6-15
Horse Manure	1.6	25-30
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
Red Clover	1.8	27
Rice Hulls	0.3	121
Rotted Sawdust	0.25	200-500
Seaweed	1.9	19
Sewage Sludge	2-6.9	5-16
Sheep Manure	2.7	16
Shrimp Residues	9.5	3.4
Slaughter Waste	7-10	2-4
Softwood Bark	0.14	496
Softwoods (Avg.)	0.09	641
Soybean Meal	7.2-7.6	4-6
Straw (General)	0.7	80
Straw (Oat)	0.9	60
Straw (Wheat)	0.4	80-127
Telephone Books	0.7	772
Timothy Hay	0.85	58
Tomato	3.3	12
Turkey Litter	2.6	16
Turnip Tops	2.3	19
Urine	15-18	0.8
Vegetable Prod.	2.7	19
Water Hyacinth	---	20-30
Wheat Straw	0.3	128-150
Whole Carrot	1.6	27
Whole Turnip	1.0	44

Table 3.1

NITROGEN LOSS AND CARBON/NITROGEN RATIO

Initial C/N Ratio	Nitrogen Loss (%)
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

Manure	% Moisture	% N	% Phos	% K
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

SAWDUST	RELATIVE DECOMPOSITION RATE
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.[18] 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.[19] 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 -10⁰C, but whose optimum temperature is 15⁰C (59⁰F) or lower. The *mesophiles* live at medium temperatures, 20-45⁰C (68-113⁰F), and include human pathogens. *Thermophiles* thrive above 45⁰C (113⁰F), and some live at, or even above, the boiling point of water.

Strains of thermophilic bacteria have been identified with optimum temperatures ranging from 55⁰C to an incredible 105⁰C (above the boiling point of water), and many temperatures in between.[20] The strains that survive at extremely high temperatures are called, appropriately enough, extreme thermophiles, or hyperthermophiles, and have a temperature optimum of 80⁰C (176⁰F) 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.[21]

Thermophilic bacteria were first isolated in 1879 by Miquel, who found bacteria capable of developing at 72⁰C (162⁰F). 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.[22]

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.[23] 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 (194⁰F) 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. pH7=.0000001 gram atom of hydrogen per liter. 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.

0 ... 7 ... 14

ACIDIC ◄··········► NEUTRAL ◄··········► ALKALINE

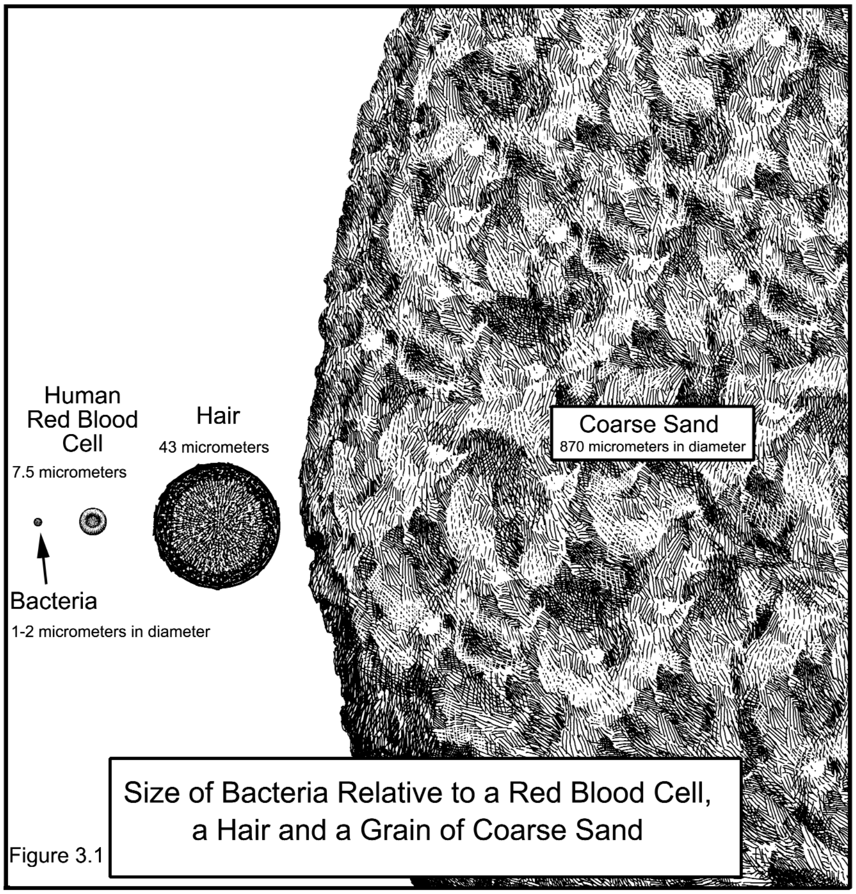
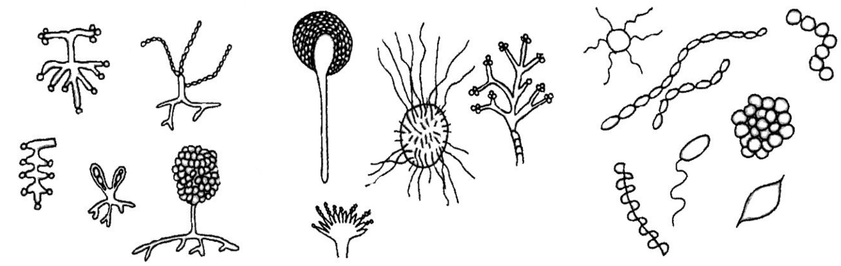


Figure 3.1 Size of Bacteria Relative to a Red Blood Cell, a Hair and a Grain of Coarse Sand

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.

Figure 3.3

COMPOST MICROORGANISMS MAGNIFIED 1,000 TIMES

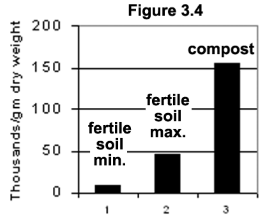


Actinomycetes	Fungi	Bacteria
100 thousand - 100 million per gram of compost	10 thousand - 1 million per gram of compost	100 million - 1 billion per gram of compost

Reproduced with permission from On-Farm Composting Handbook. NRAES-54, published by NRAES, Cooperative Extension, 152 Riley-Robb Hall, Ithaca, New York 14853-5701. (607) 255-7654. Quantities of microorganisms from: Sterritt, Robert M. (1988). Microbiology for Environmental and Public Health Engineers. p. 200. E. & F. N. Spon Ltd., New York, NY 10001 USA.

Fungi Populations in Fertile Soil and Compost

Figure 3.4



Source: U.S. EPA (1998), EPA53 0-B-98-001 March, 1998

Bacteria Populations in Fertile Soil and Compost

Figure 3.5

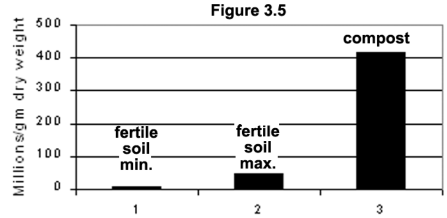


Table 3.6

MICROORGANISMS IN COMPOST

Actinomycetes	**Fungi**	**Bacteria**
Actinobifida chromogena	*Aspergillus fumigatus*	*Alcaligenes faecalis*
Microbispora bispora	*Humicola grisea*	*Bacillus brevis*
Micropolyspora faeni	*H. insolens*	*B. circulans* complex
Nocardia sp.	*H. lanuginosa*	*B. coagulans* type A
Pseudocardia thermophilia	*Malbranchea pulchella*	*B. coagulans* type B
Streptomyces rectus	*Myriococcum themophilum*	*B. licheniformis*
S. thermofuscus	*Paecilomyces variotti*	*B. megaterium*
S. thermoviolaceus	*Papulaspora thermophila*	*B. pumilus*
S. thermovulgaris	*Scytalidium thermophilim*	*B. sphaericus*
S. violaceus-ruber	*Sporotrichum thermophile*	*B. stearothermophilus*
Thermoactinomyces sac chari		*B. subtilis*
T. vulgaris		*Clostridium thermocellum*
Thermomonospora curvata		*Escherichia coli*
T. viridis		*Flavobacterium* sp.
		Pseudomonas sp.
		Serratia sp.
		Thermus 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.[24]

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."* [25] 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.[26] 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.[27] 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,[28] while another researcher found that above 65⁰C, the organisms in the compost were almost purely *Bacillus stearothermophilus*.[29]

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^{0}C (111^{0}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^{0}C-52^{0}C (111^{0}F-125.6^{0}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^{0}C (158^{0}F),[30] 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.[31] Most fungi cannot grow at 50^0C because it's too hot, although *thermophilic fungi* are heat tolerant. Fungi tend to be absent in compost above 60^0C and actinomycetes tend to be absent above 70^0C. Above 82^0C biological activity effectively stops (extreme thermophiles are not found in compost).[32]

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).[33]

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]."* [34]

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.[35] 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.[36] 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."* [37] 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 matter 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.[38]

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.[39] 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).[40] 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).[41] 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."*[42] 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."* [43]

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."* [44] 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.

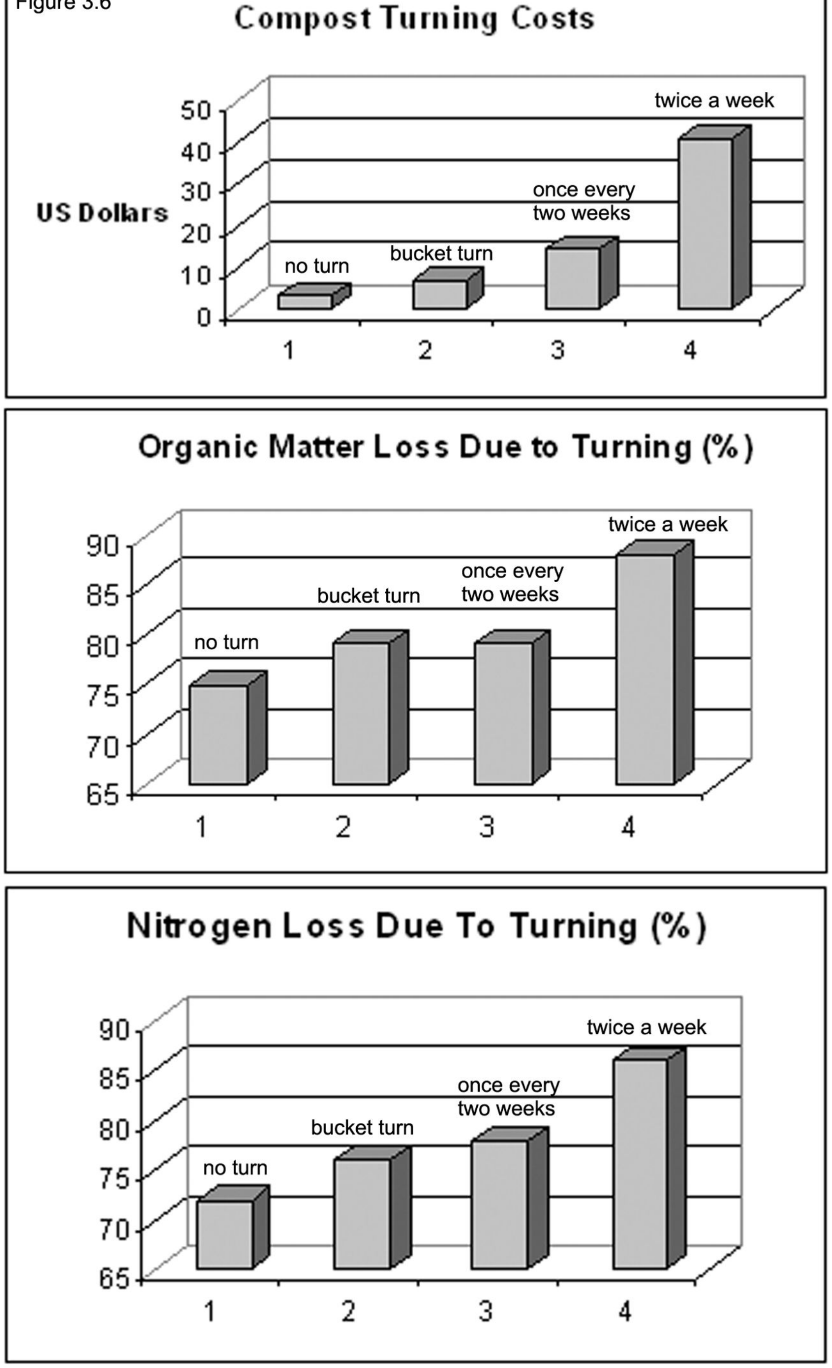
Much of compost's current popularity in the West can be attributed to the work of Sir Albert Howard, who wrote *An Agricultural Testament* in 1943 and several other works on aspects of what has now become known as organic agriculture. Howard's discussions of composting techniques focus on the Indore 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



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."* [45]

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."* [46] 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), afterwhich 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.[47]

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 expenditure 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."* [48]

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.[49]

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.[50]

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."* [51] Others state, *"No data in the literature indicate that the addition of inoculants, microbes, or enzymes accelerate the compost process."*[52]

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 compost 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.[53] 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."*[54] 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.[55] 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.[56] 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."* [57]

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 mayonaisse 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."* [58] 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.[59]

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%.[60] 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.[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.[61] 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.[63]

Fungi in compost produce a substance that breaks down petroleum, thereby making it available as food for bacteria.[64] 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.[65] 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.[66]

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.[67] Some of this degradation is due to the efforts of fungi at lower (mesophilic) temperatures.[68]

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.[69]

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.[70]

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."* [71] 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.[72]

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.[73] 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.[74]

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.[XX]

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.[75] 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.[76]

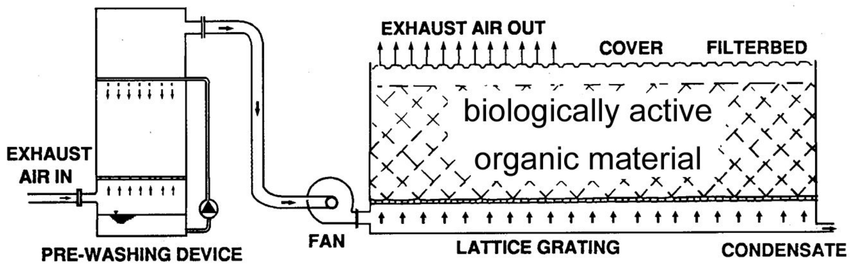
Compost defends plants from diseases

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.[77]

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.[78] 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,[79] *Fusarium oxysporum* in potted plants, and gummy stem blight and damping-off diseases in squash.[80] 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: *Phytophtora*, *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.[81]

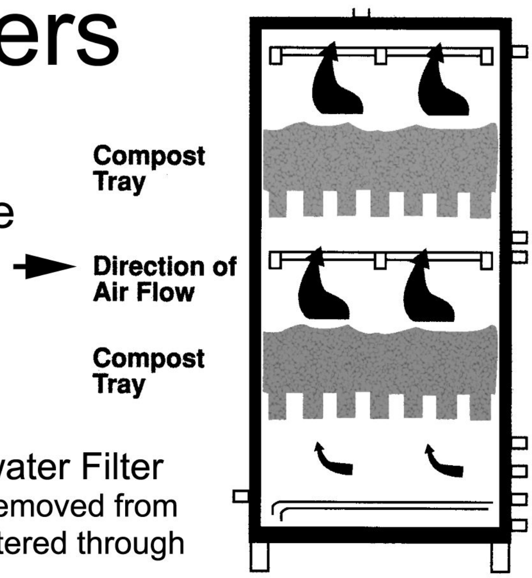
In fact, compost *tea* has also been demonstrated to have dis-



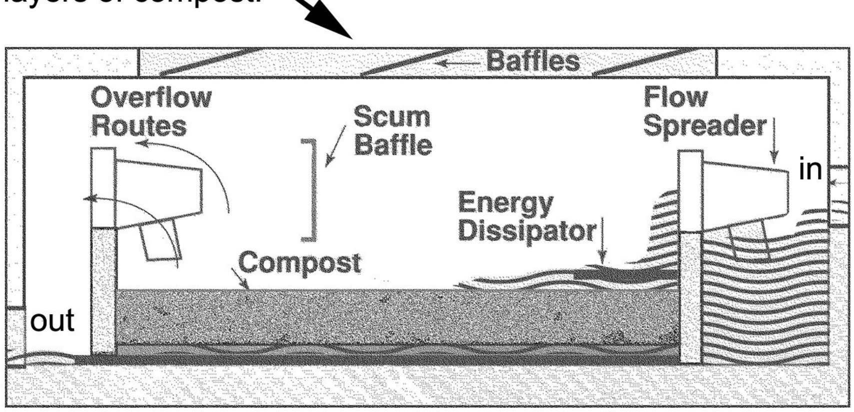
Biofilters

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.[82] Powdery mildew (*Uncinula necator*) on grapes was very successfully suppressed by compost tea made from cattle manure compost.[83] *"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."* [84]

Besides helping to control soil diseases, compost attracts earthworms, aids plants in producing growth stimulators, and helps control parasitic nematodes.[85] 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.[86]

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.[87]

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.[88] 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.[89]

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.[90]

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.[91]

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%.[92] 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 *Eisenis 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.[93]

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.