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PREPARATION OF COMPOST FROM THE TOILET FOR USE IN THE GARDEN

Summary: *This technical paper discusses how to produce compost from human and vegetable refuse that is safe and valuable for growing food. It gives a brief history and background of dealing with human waste, possible pathogens in it, the length of time that the pathogens persist in soil and crops, testing for pathogens with indicator organisms, and Environmental Protection Agency biosolids regulations for pathogen control. The process of composting is discussed. Vegetables were grown with soil treated with cured compost, the vegetables were harvested and samples of the vegetables, compost and soil were prepared to test for pathogens. Results and interpretation of results are presented.*

HISTORY AND BACKGROUND

Human refuse, feces and urine, when processed by microorganisms, forms an excellent humus which can be added to garden soil to produce food. It is an essential part of the nutrient cycle: food is grown, food is eaten, refuse is excreted, is composted and returned to the soil. The bacteria and fungi and other organisms that breakdown, or compost, the leaves and trees in the woods, manure from animals, and vegetable and fruit materials, will also breakdown human refuse to a pleasant smelling, pathogen-free humus. As these organisms eat this organic refuse, they heat the pile of refuse to a high enough temperature to inactivate the pathogens which might be present, if properly managed. The humus that results is an excellent soil fertilizer and conditioner.

This nutrient cycle does not function in most of the United States and other developed countries of the world. Most human refuse is put in purified drinking water and flushed down a toilet to be treated in a waste water treatment plant or a septic system. Or it goes by a straight pipe into a stream to cause polluted water for everyone down stream, unless they are far enough away that the stream has a chance to treat it, which is usually not the case.

For centuries in Asia, night soil (raw human refuse) has been placed directly on the soil to grow food. This approach to growing food allowed many of the disease pathogens in the night soil to survive and to be consumed by those eating the food or drinking the contaminated water. Typhoid fever, dysentery, cholera, viruses and various parasitic worms can all be transmitted in this way. Many places in Asia are now composting their waste and inactivating pathogens. In this way, they are putting the waste to appropriate, safe and healthy use by composting it before adding it to their gardens.

About one thousand pounds of human refuse per person per year in the United States and other developed countries is wasted and pollutes water that carries it to the treatment plant.. Until recently, developed countries had not learned the wisdom of recycling the refuse for reuse in growing crops. Although, there is a movement in that direction through the Environmental Protection Agency (EPA) Part 503 regulations on pathogen reduction in sewage sludge through composting and other means to achieve pathogen inactivation. These 503 Regulations are discussed later.

POSSIBLE PATHOGENS IN HUMAN WASTE

Pathogens in Manure: A variety of pathogens can exist in human refuse, which includes urine and feces. The human refuse can have viruses, bacteria, protozoa, and worms (helminths). There are a number of each type that are possible. In urine, bacteria can cause typhoid or paratyphoid fever and worms can cause schistosomiasis. In feces, viruses can cause diarrhea, infectious hepatitis and poliomyelitis; bacteria can cause typhoid fever, paratyphoid fever, food poisoning, dysentery, cholera, and diarrhea; protozoa can cause diarrhea dysentery, colonic ulceration, and liver abscess. Some of the worm parasites that can be present are hookworm, various flukes, pinworm, various tapeworms, roundworm, and threadworm. These pathogens are of concern in human refuse. This material is paraphased from J.C. Jenkins (1994), who has produced an excellent reference on composting human refuse.

How long do pathogens persist in soil and on crops?

IN SOIL: The length of time that the pathogens survive in soil depends upon soil moisture, pH, type of soil, temperature, sunlight, and organic matter.

ON CROPS: Bacteria and viruses cannot penetrate undamaged vegetable skins, but they can survive on the surfaces of vegetables, especially root vegetables. Sunshine and dry air can help kill the pathogens. If there is any concern about pathogens, compost should be applied to long-season crops at the time of planting so that sufficient time passes for the pathogens to die.

PATHOGEN	SURVIVAL TIME
Fecal coliform bacteria	25 days in summer, 36 days in winter
Salmonella bacteria	50 days
Viruses	120 days in warm soil, 180 days in cold soil
Cysts of protozoa	not more than 10 days
Round worm eggs	several years

TESTING FOR PATHOGENS

Indicator Organisms: The need to determine the suitability of water for drinking and bathing was recognized over 100 years ago. At that time outbreaks of typhoid fever and cholera were related to water contamined with fecal wastes. To protect public health, simple, reliable and rapid methods were required to detect and count microorganisms. Since pathogens are not easily detected or cultured, methods have been developed which detect the presence of "indicator" organisms (Hach Co., 1992). If these organisms are absent, the probability of the existence of bacterial pathogens in the water is minimal. The concept of "indicator" organisms was introduced and is the basis for most microbiological water quality standards today.

Gastrointestinal pathogens known to have caused outbreaks of intestinal disease are largely from the Enterobacteriaceae family. Diseases caused by these organisms are spread by water contaminated with fecal matter from humans and other warm-blooded animals. In order for an organism or group to be a reliable "indicator" of the possible presence of intestinal pathogens in a water supply, the "indicator" must be exclusively of fecal origin, and must be consistently present in fresh feces. One organism used as a bacterial indicator of pollution is the coliform bacteria, Escherichia coli.

The total coliform group is the most inclusive indicator classification, including: Escherichia, Citrobacter, Klebsiella and Enterobacter. Contamination indicated by the presence of total coliforms is indicative of inadequate disinfection of drinking water. For these reasons, the microbiological quality standards for drinking water of the United States and of most developed countries are based on the measurement of the total coliform population.

Coliforms of fecal origin are part of the population of total coliforms and are represented by thermo-tolerant total coliform bacteria capable of growth with acid and gas production at 44.5C + 0.2C. World Health Organization Guidelines require that fecal coliform counts should be zero per 100 mL of sample in all water supplies, piped or unpiped, treated or untreated.

—PATHOGEN DENSITY REQUIREMENT IN PART 503: For a class A compost which can be given or sold to the general public, the density of fecal coliform in compost must be less than 1000 Most Probable Number (MPN) per gram of total solids (dry weight basis) at the time of use or disposal.

Method for Enumeration of Indicator Organisms: Of the primary techniques for the routine detection and enumeration of indicator bacteria, the most probable number (MPN) technique is used here. The MPN test is done by using a specified number of tubes (depending on the expected population in the sample) containing a specific medium and the sample. Each tube is examined for a positive response indicative of the growth of the organism(s) sought. Based on the number of tubes giving a positive result, the MPN number of organisms present is determined by using a table of numbers determined statistically.

PROCESS OF COMPOSTING

Leaves, plants, trees and organic matter in the woods have been composting for millions of years. The bacteria and other soil creatures use these materials as their food, so that they can grow and reproduce. Human feces and urine will also compost, but there may be pathogens present in these materials. Composting can kill the pathogens if done in the proper manner.

Compost from a typical composting toilet usually does not achieve a very high temperature, so that some pathogens may still be alive in the compost. The pathogens can be killed by composting in an outdoor pile. The temperature is raised to a sufficiently high level by soil microorganisms for a long enough period of time: 150F (65C) for an hour, 120F (50C) for 24 hours or 115F (46C) for a week (Fig. 1). The compost pile must be about a meter cube.

Effective composting requires sufficient moisture (50-75%), "dry browns" and "wet greens" in proper ratio, air available throughout the pile and soil organisms. The "dry browns" are leaves and grass that are no longer green which are high in carbon; the "wet greens" are grass and leaves which are still green or have their natural living color which are high in nitrogen. It is desirable to have a ratio of 25-30 carbon to 1 nitrogen or much more of the dry browns to the wet greens. The exact ratio is not too critical, but if your pile is not working very well try to get closer to the ratio and/or add some rich soil. If nitrogen is low some urine can be added. The pile needs to be turned so that all materials reach the desired temperature at some time during the process.

In the experience of the author, daily additions of peelings, stems and stalks from vegetables and fruits keep the pile loose and temperature up. Piles which are tight have lower temperatures, possibly due to lack of air which, in turn, prevents the various organisms from working. Piles receiving very moist air will remain moist and tight due to lack of evaporation of moisture produced by composting and that being deposited on the pile by the users. The composting process will be slowed or inhibited by excess moisture concentrations.

Another option to achieve the high temperature for pathogen kill is compost solarization, as described by Pullman (1984). This is accomplished by placing a 7.5 centimeter (3 in) layer of compost from the toilet on the ground and covering it with a clear plastic sheet (1 or 4 mil thickness) during the summer, when the outdoor temperature is over 27C (80F). The compost needs to be quite smooth and free of any plants or lumps so that the plastic film will have intimate contact with the soil and compost. The edges should be sealed so that moisture is not lost. The temperature should reach 55 to 60C (131 to 140F) for about two weeks. The compost should be very moist (50-75%) but not soggy, such that water can be squeezed out of it.

The EPA published Part 503 biosolids regulations in the Federal Register on February 19, 1993. A major focus of these regulations is pathogen control. A standard is set in which compost must be held at 55C for a period of time, dependent on the process used to thermally inactivate pathogens. For within-vessel composting or the static aerated pile composting the temperature must be held at 55C or higher for three days. For windrow composting, the temperature must be held at 55C or higher for 15 days with a minimum turning of the windrow five times. This high temperature composting insures complete inactivation of pathogens.

Safe compost: A year in a properly operating compost toilet kills most all pathogens, except possibly the ova of some of the worms. Of course, benefical organisms can survive through most of this as they do in the soil of any garden. Freezing will inactivate the ova of all but the roundworm. A couple of days exposure to hot sunlight or two weeks of solarization (discussed above) will inactivate them. As an extra precaution, vegetables grown in soil treated with the compost should be washed thoroughly since the ova can not be taken into the plant and washing would remove them from the outside of the plant.

Safety Zone for Pathogen Death

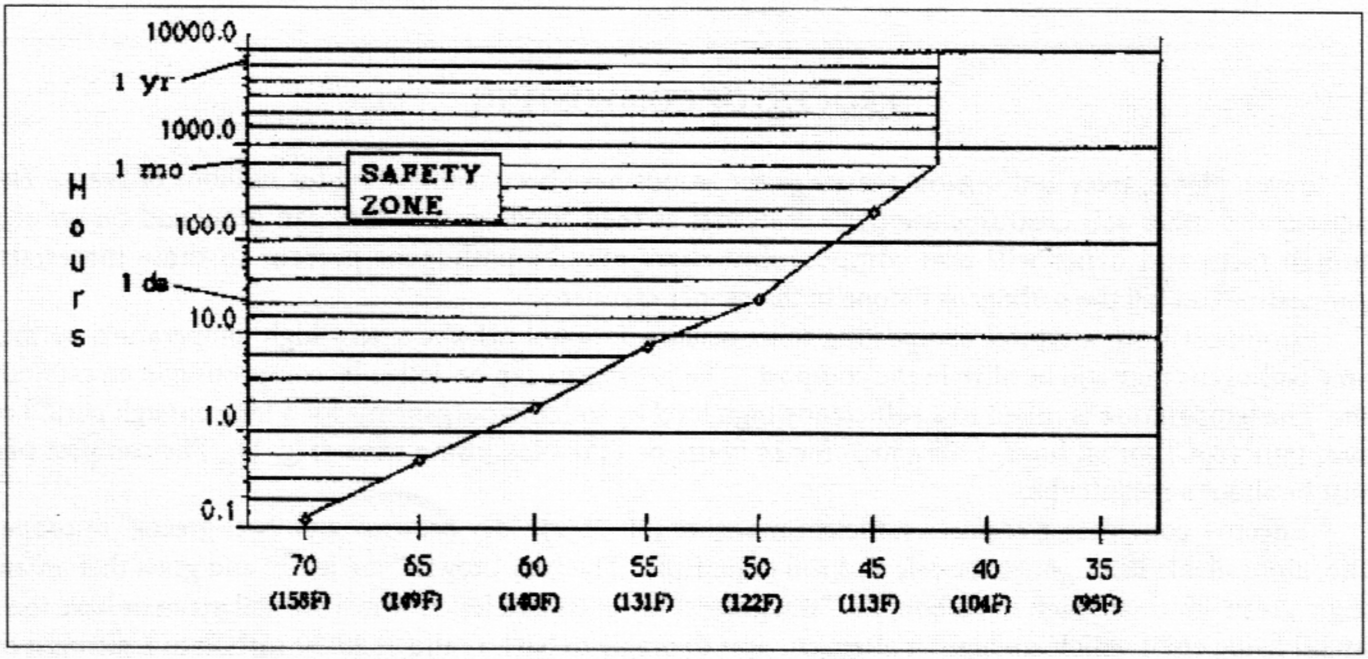

Figure 1

This graph is appropriate for enteric viruses, Shigella, Taenis, Vibrio cholera, Ascaris (roundworm), Salmonella and Entamoeba histolytice. Source: Feachem et al., (1980)

Super safe compost: To have confidence in your compost for your garden, you can permit just your family to use your compost toilet. Then you know what has been deposited in it. Another option is to just spread the compost from the toilet on tree and bush crops.

HARVEST AND TESTING—Results from ASPI

Sampling of Vegetables, Soil and Compost: In August and September, 1996, three vegetables, compost from the carousel toilet and soil in which the vegetables were grown was sampled and sent to A&L Analytical Laboratories, Inc. (411 N Third Street, Memphis, TN 38105). The gardens are all State Certified Organic. The vegetables were washed thoroughly with water, dried and placed in plastic ziplock bags and put in the refrigerator till the rest of the samples were obtained. Several soil samples were taken and combined and a sample taken from this combination for analysis. Soil samples were taken with a trowel and placed in plastic ziplock bags and refrigerated. The compost samples were collected in a manner similar to the soil samples. All of the samples were placed in an insulated container with Freeze Pac to keep the samples cool during shipment. They were sent overnight for delivery the next day.

The laboratory results of the tests are given in Table 1. The "Compost Age" lists the months in the composting toilet without deposit (months curing in the garden). In the "MPN" column, the "<" refers to the fact that the laboratory analyst found no positive results for pathogens in the samples.

Table 1 Test Results

Item	Sample Date	Compost Age -months-	Fecal Coliform MPN/gram -cells/g dry wt-
Jeru. artichoke (edible portion)	Aug.	12(12)	<
Soil (Ja)	"	12(12)	88
Tomatoes	"	12(5)	<
Compost (Tm)	"	12(5)	<
Soil (Tm)	"	12(5)	<
Compost (Ct)	"	12(0)	<
Jeru. artichoke (edible portion)	Sept.	12(13)	<
Tomatoes	"	12(6)	<
Green beans	"	12(6)	<
Soil (t&b)	"	12(6)	<
Compost (Lt)R 69%H2O	"	0	110
Compost (Lt)L 76%H2O	"	0	6722
Tomatoes (Jp)	"	--	<

Interpretation of Results: The pathogen test results for the soil, the compost, and the vegetables are discussed below.

1) **Soil:** The soils in which the Jerusalem artichokes (Ja), the tomatoes (Tm), and the tomatoes and beans (t&b) (Table 1) were grown, were sampled and tested for pathogens, as fecal coliform. This soil, except for that in which the Jerusalem artichokes were grown, was free of pathogens. The (Ja) soil was not fenced in and was exposed to the use of domestic animals; this could account for the MPN of 88. The soil in the fenced in gardens was free of fecal coliform; this increases ones confidence that the vegetables grown in it are also free of pathogens. If the soil is free of the pathogens, certainly the vegetables grown on it would be free of them, or at least they could not get them from the soil.

2) **Compost:** The two samples of raw compost, (Lt)R and (Lt)L, from about a foot from the top of the pile, still in use, in the ASPI toilet in the library had MPN fecal coliform values of 110 on the right side and 6722/gram of dry weight compost on the left. The difference between the two sides of the pile is due to the reconstruction of the right side including layers of twigs at the bottom and a foot from the bottom. These allow more air to enter the pile so that the various organisms there can metabolize the material deposited. The pile had been reconstructed about 3 months previous to the sampling. The additional air definitely aided the composting process. In addition, the more air that can be trapped in the pile, the better the pile will heat up and inactivate the pathogens that might be present. Fecal coliform bacteria found in the raw compost are expected in a pile that is actively being used.

In the carousel toilet, after a year of composting at low temperature with no deposit on the pile in the toilet and then for about 7 month storage outside in a small pile or in the garden soil there was no fecal coliform detected. The pile in the toilet and outside had experienced temperatures below freezing several times during the winter season. Freezing is another factor that helps to inactivate pathogens.

The August compost samples, (Tm) and (Ct), are most probably free of fecal coliform, viruses and helminth ova. It meets the Part 503 standard of an MPN of less than 1000/gram dry weight of sample. However, since the compost piles probably never reached 55C for any known period of time, it did not meet the time/temperature requirement of 55C (131F) for 24 hours required to guarantee there is no helminth ova present.

Pinworms, hookworms, and whipworms were probably killed due to drying up or freezing. Roundworm ova are not killed by freezing. The compost had been frozen several times, so roundworms were the only possible surviver. The 12 months spent in the compost pile has been shown to rid materials of pathogens (Feachem, et al. (1980)). The compost spread on the ground for several months would have provided the opportunity for the sun to kill the roundworms. In addition, roundworm ova cannot be taken into plants, so thorough washing can remove them. If the compost and the soil in which the vegetables are grown are free of pathogens, the vegetables grown in it would be also.

If there is concern for the presence of pathogens in a compost, it can be placed on a pile that is about a one meter (3.28ft) cube to allow thermophilic composting to occur. For short term, if the pile reaches and stays at 55C (131F) for 24 hours, all pathogens will be inactivated, for longer term, at 46C (115F) for one week, all pathogens will be inactivated (Fig. 1). This process produces compost which will provide excellent soil enrichment for growing fruits and vegetables. The importance of doing a careful job with managing the composting operation can be realized when recalling the possible pathogens present that can be inactivated by appropriate composting of the waste.

3) Vegetables: The Jerusalem artichokes, tomatoes and green beans from the test plot were clear of pathogens according to the laboratory test results for MPN values for the indicator organism, fecal coliform. Since the compost was stored in the soil for 8 months prior to the harvesting of the vegetables, the freezing temperatures and the exposure to sunlight would have inactivated the helminth ova, including the roundworm ova. The vegetables were suitable to eat. The tomatoes (Jp) from the Jackson plot had no compost from a toilet and a test result similar to the other vegetables further confirms their freedom from pathogens.

Future Research

Low temperature composting occurring in the compost toilet probably inactivates pathogenic bacteria and viruses, but the roundworm ova may not be inactivated by short term composting, say 3 to 4 months, nor by temperatures of -23C. (10F), as are the other helminth ova, worm ova. Thus, it would be helpful to check for roundworm ova in some samples from the compost to verify that they too can be inactivated by composting in the toilet pile without additional composting. Exposure to two days of sunlight will also inactivate the roundworm ova as mentioned above. Another interesting study would be the addition of fine rock dust to the compost and possibly even the compost toilet to determine the benefical effects that it can have on the composting process and the resulting plant growth.

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