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Composted Animal Manures: Precautions and Processing

Compost is made by recycling organic materials such as yard trimmings, wood chips, food scraps, and animal manures in a controlled process. The process employs microorganisms to transform the raw materials so that they are no longer recognizable. Finished compost is a crumbly, earthy-smelling, dark material that looks like a commercial potting-soil mixture. Used as a soil amendment, compost can

- improve soil structure, making the soil easier to cultivate and encouraging root development
- provide plant nutrients and enable their increased uptake by plants
- aid water absorption and retention by the soil, reducing erosion and run-off and thereby protecting surface waters from sedimentation
- help bind agricultural chemicals, keeping them out of waterways and protecting groundwater from contamination
- increase levels of beneficial soil organisms

Quality compost is thoroughly decomposed and pathogen-free. Pathogens hazardous to human health can be introduced to compost when animal manures (urine and feces) are used as raw materials. Various kinds of animal manures are available in Hawaii, and this publication is written to inform those who might be considering the use of animal manures in composting.

Indiscriminate use of compost products that contain pathogens can create health risks for humans and animals by dispersing pathogens into the environment. Therefore, it is important that when animal manures are used, the resulting compost products have been sufficiently sanitized to reduce pathogen contents to levels lower than those normally considered "risk levels."

Composting and sanitization

In composting, many types of nonpathogenic microorganisms transform complex organic materials into simpler compounds through the decomposition processes of mineralization and humification. When a compost pile is correctly constructed and managed, the activity of these decomposer microorganisms generates heat sufficient to kill pathogenic microorganisms. If the right conditions are not present for the decomposition activity to generate heat, the process may not result in sanitization.

For sanitization to take place during the composting process, the entire mass of organic material must be exposed to lethal temperatures for a suitable length of time. Because these temperatures develop in the interior of the pile, turning the pile is an important part of compost management. Undecomposed material from the top and sides of the pile are rotated toward its center by turning the pile. After several turnings, usually at intervals ranging from one to three weeks, all of the materials in the pile should have been exposed to the conditions that result in sanitization.

Composting is completed when the pile no longer generates heat and the original organic materials are no longer recognizable. The composting process has then reached an endpoint and is more or less biologically stable. Finished compost is not a good substrate for growth of pathogens, but if it has been recontaminated with fresh manure, it may act as a carrier for pathogens.

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General guidelines for attaining sanitization of composts that include animal manures are the following:

- If composting materials are contained in a vessel and temperatures are uniform throughout the mass of composting materials, a minimum of three consecutive days with compost temperature above 55°C (131°F) is required to achieve sanitization.
- If composting materials are in a turned pile or turned windrow system, the requirement is a minimum of 15 days in which temperatures in the pile are above 55°C and five turnings during that high-temperature composting period.
- The finished compost must be biologically stable so that pathogen regrowth from the pile itself does not occur.
- Finished compost must not be reinoculated by contaminated equipment (loaders and turning devices), by the addition of unprocessed feedstock (fresh or partially composted animal manures), or by leachate run-off from another pile.

Temperature of a compost process can be quantitatively measured and controlled to ensure an adequate level of sanitization. Although there are no federal regulations on composting manures, the U.S. Environmental Protection Agency's "503" regulations for biosolids composting provide guidelines on monitoring temperatures for pathogen reduction.

Because a rise in temperature during composting is the direct result of bio-oxidation activity by microbes, conditions promoting bio-oxidation should be encouraged by careful planning and management of the composting process. These conditions include adequate moisture and aeration, as well as a sufficiently low carbon-nitrogen ratio of the aggregate raw materials of the compost pile. The carbon-nitrogen ratio is low for materials such as fresh lawn clippings and animal manures (around 20 parts carbon to 1 part nitrogen). The carbon-nitrogen ratio is high in materials such as sawdust or wood chips (where the ratio may be 400 parts carbon to 1 part nitrogen). The composting process is slowed—and microbial heat generation is inhibited—by insufficient amounts of materials rich in nitrogen (such as fresh, green plant materials, food scraps, or animal manures) in relation to the amounts of carbon source (such as wood chips, shredded paper, dry vegetation like straw or palm fronds, and other such organic materials high in lignin and cellulose).

The finished compost product should be analyzed to determine the extent of sanitization before it is marketed. Laboratories use two general methods to determine the pathogen content of composts, waters, and other media suspected to be sources of pathogens. The first method is to search for a particular pathogen, such as *Salmonella* species. Finding such a pathogen indicates a problem. The second method is to measure the populations of particular "indicator" groups of pathogens, such as total coliforms (of which *E. coli* is one) or fecal streptococci. If the populations of these indicator groups are low, it is statistically probable that the numbers of individual pathogens of particular concern that are known to be associated with these groups (although in much smaller numbers, proportionally) is also low. Low numbers of an indicator group allows the assumption that the associated pathogens of particular health concern are not present.

Pathogenic microorganisms

A different group of pathogens is present in human wastes (Table 1) than is present in animal manures (Table 2). A comparison of these lists reveals the following:

- Viruses that infect humans are not found in animal manures.
- Few fungal diseases of importance to humans are found in animal manures, although some pathogenic fungi found in the environment can take up residence in excreted animal manures and thus get into compost.
- Bacterial diseases are present in animal manures, and among them the most important threat to human health is *Salmonella* sp.

Protozoan and helminth parasites may be present in animal manures and are a potential public health problem. Infection by these organisms mainly occurs when fresh animal manures are handled. Composting greatly reduces their numbers, although if lethal temperatures are not reached in the process, eggs of some helminth parasites can survive to pose a health threat. The threat of helminth parasites is virtually eliminated if the feces of dogs, cats, and carnivores in general are not included for composting.

What happens to pathogenic microorganisms after they leave their host?

When fecal pathogens leave their host, they are exposed to the rigors of the external environment. Most pathogens cannot survive long or reproduce outside of their host, but under favorable environmental conditions, there are some that can endure. Composting conditions are not a suitable environment for pathogens and make their survival more difficult. Managing the conditions of the composting process to eliminate pathogens involves manipulating the compost pile's contents, moisture level, and oxygen supply to favor development of decomposing microorganisms that create an environment in which it is difficult for pathogens to survive. Factors affecting the composting process as related to pathogen survival are discussed in the following paragraphs.

Available organic material and nutrients. The survival of pathogens in animal waste depends on the availability of suitable food—organic materials that they can metabolize. Pathogenic bacteria and fungi generally can metabolize readily available organic compounds such as the simpler alcohols, organic acids, and sugars, whereas they generally cannot metabolize complex compounds such as cellulose, lignin, and humic compounds. This limitation places the pathogens present in animal manures in an unfavorable competitive position with respect to the nonpathogenic, decomposer microorganisms that are indigenous to the rest of the materials normally present in a compost pile and are normally present in far greater numbers. Pathogen metabolism and growth are thus limited by shortage of utilizable organic materials and nutrients.

Moisture. The moisture level in fresh animal manures is usually adequate to support pathogen growth. Moisture levels suitable for composting to proceed also are suitable for pathogen survival. However, at moisture levels lower than 25 percent, all microbial growth slows and eventually ceases. If the moisture content of cured, stabilized compost remains lower than 25 percent, conditions are not conducive to regrowth of pathogens. Unfortunately, compost at such moisture levels is difficult to use because it is too dry, and its dust may cause allergic reactions in some people. For practical use of finished compost, its optimum moisture content is 40–60 percent. Therefore, manipulating the mosture

Table 1. Possible pathogens found in human waste.

Pathogen	Disease
Virus	
Enterovirus	Gastroenteritis
Rotavirus	Gastroenteritis
Parvovirus	Gastroenteritis
Adenovirus	Respiratory infections
Hepatitis A virus	Viral hepatitis
Polio virus	Poliomyelitis
Coxsackie virus	Meningitis
Bacteria	
Salmonella (1700 serotypes)	Salmonellosis
Shigellae	Shigellosis
Mycobacterium tuberculosis	Tuberculosis
Vibrio cholerae	Cholera
Escherichia coli	Gastroenteritis
Yersinia enterocolica	Gastroenteritis
Clostridium perfringens	Gastroenteritis, gangrene
Clostridium botulinum	Botulism
Listeria monocytogenes	Encephalitis
Fungi	
Candida sp.	Mycoses (skin and systemic)
Tricosporon cutaneum	Skin mycosis
Aspergillus fumigatus	Lung mycosis
Trichophyton sp.	Skin mycosis
Epidermophyton sp.	Skin mycosis
Microsporum sp.	Skin mycosis
Protozoa	
Entamoeba sp.	Amoebic dysentery
Giardia lamblia	Giardiasis
*Balantidium coli (*rare)	Dysentery
Naegleria fowleri	Primary amoebic meningoencephalitis
Acanthamoebe (rare)	Meningoencephalitis
Helminths	
Ascaris lumbricoides	Human large round worm
Ancylostoma sp.	Hookworm
Necator amaricanus	Common hookworm of man
Enterobius vermicularis	Human pinworm
Strongyloides stercoralis	Small roundworm
Trichuris trichiura	Human whipworm
Taenia solium	Human tapeworm
Hymenolepsis nana	Dwarf tapeworm

level during the composting process is not a convenient method for affecting pathogen survival.

Temperature. The ability of pathogenic microorganisms to survive under high temperatures varies from one group to another and with the prevailing environmental conditions. The most dangerous of the pathogens in animal manures, such as *Salmonella* sp. and some serotypes of *E. coli*, are not thermophilic (heat-loving), do not form heat-resistant spores, and can be eliminated by heat treatment. The threshold of heat resistance, or tolerance, of an individual type of pathogen must be surpassed for sanitation to be effective. Whether a particular heat level is lethal is a function of both the temperature reached and the duration of exposure to that temperature.

Oxygen supply. Decomposition occurring during composting is primarily the result of aerobic microorganisms performing biological oxidation reactions, so an adequate air supply is required. The increased temperatures resulting from such reactions in a compost pile cannot occur unless sufficient oxygen is available. In the absence of oxygen, anaerobic microorganisms are

Table 2. Possible pathogens found in animal waste.

Pathogen	Disease	Host
Virus	None	
Bacteria		
Salmonella (1700 serotypes)	Salmonellosis	Animals and birds
Shigella sp	Bacillary dysentery	Nonhuman primates
Escherichia coli	Gastroenteritis	Many animal hosts
Mycobacterium sp. (very rare)	Tuberculosis	Cattle, via milk
Yersinia enterocolica (rare)	Gastroenteritis	Animals and poultry
Clostridial diseases	Gastroenteritis, gangrene, botulism	Normal intestinal flora and soil
*Leptospira interrogans**		
Listeria monocytogenes	Encephalitis	Animals, birds and soil
Campylobacter (Vibrio)	Gastroenteritis	Cattle and sheep
Chlamydia psittaci	Psittacosis	Birds
Fungi		
Candida sp.	Mycoses (skin and systemic)	Animals,birds,fruit,environment
Aspergillus fumigatus	Lung mycosis	Environment
Protozoa		
Giardia lamblia	Giardiasis	Animals, esp. beaver and muskrat
Balantidium coli (very rare)	Dysentery	Swine and primates
Cryptosporidia	Dysentery	Animals, esp. calves
Toxoplasma	Toxoplasmosis	Cats
Helminths		
Ascarids (*A. suum*)	Large round worm	Swine
Toxocara (*T.canis and T.cati*)	Visceral larva migrans Ocular larva migrans	Dogs and cats
Ancylostoma sp.	Hookworm disease	Dogs and cats
Echinococcus (tapeworm)	Hydatid disease	Dogs
Strongyloides stercoralis	Small roundworm	Dogs and cats

**Leptospira interrogans* is shed from the animal via the urine and may contaminate the feces. However, these organisms do not survive in dry environments nor do they survive the composting process.

favored, and their activities do not cause heat to be generated to the extent needed for sanitation. Therefore, compost piles should be prevented from becoming too wet and should be turned to improve aeration.

Microbial competition and antagonism. The number of indigenous (native, or natural) microorganisms involved in composting is enormous. By contrast, the population of pathogenic microbes in a compost pile is usually numerically small. When the conditions of composting mentioned in the preceeding paragraphs are ideal for decomposer microorganisms, they are less than ideal for pathogenic microorganisms. By their sheer numbers, the decomposers can effectively compete for food sources, starving out the pathogens. Pathogens also can come under direct attack and be consumed by certain decomposers.

How are pathogens measured and monitored?

To avoid the necessity of analyzing compost for all types of pathogens, it is common to analyze for "indicator" microorganisms. Because of the wide array of pathogens that could be present in raw animal manures, a thorough analysis of a compost pile for its entire pathogen content would be expensive. It is more practical to select a few representative pathogens that are easy to identify and quantify and are likely to be present in most animal manures. However, one of the most controversial aspects of the production of safe compost is the degree to which indicator organisms must be reduced in order to have an adequate level of sanitization.

Research has shown that counts of total coliforms, fecal streptococci, enterobacteria, certain viruses, and parasite ova can serve as indicators. For an indicator microorganism to be reliable, it must satisfy four requirements:

- It must be present in sufficiently great numbers in the raw material being composted.
- It must have the same reactions to conditions (for example, the same heat-resistance threshold) as the pathogen or group of pathogens it is being used to indicate.
- It must have a resistance threshold greater than that of the targeted pathogens.
- Tests for its presence and counts of its numbers must be simple and inexpensive.

The methodology which seems to be increasingly used by laboratories for pathogenicity evaluation of compost products is to test for the presence of *Salmonella* species, a particularly important pathogen, or to test for two indicator groups microorganism, total coliforms and fecal streptococci.

Summary

The possibile presence of pathogenic microorganisms in compost is a major challenge for compost producers. Composted animal manures can be used in many beneficial products, but they must be properly processed. By *not* using wastes from dogs, cats, and other carnivores (including used bedding materials and "litter" products), a substantial part of the potential risk to human health from composting animal manures can be avoided. The most important conditions with respect to sanitization are

- The composting process must be thorough: all parts of the compost pile—the entire mass of organic materials—must be exposed to temperatures of 55°C (131°F) or more and maintained at that level for at least three days.
- The composting process must be complete: finished compost is biologically stable and no longer conducive to the growth of pathogens.
- The finished compost must not be reinoculated with pathogens.

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