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COMPOSTING PROCESS AND DEVICE



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FIELD OF THE INVENTION

This invention relates to a composting process and a device for carrying
5 out the process. The invention particularly relates to a composting process in
which physiochemical conditions selected from the group including
temperature, pressure, humidity and oxygen level, may be controlled and a
device in which the controlled composting process can be conducted.

10 BACKGROUND OF THE INVENTION

The safe and effective disposal of the ever-increasing tonnage of waste
produced worldwide is a serious ongoing problem. The disposal of waste into
landfill sites or by incineration are not long term sustainable practices as they
do not take into account the future environmental cost of water, soil and air
15 pollution.

In contrast, composting technology has the potential for recycling waste,
especially organic waste, into useable products without future environmental
liabilities. Composting is a biological process in which microorganisms are
used to break down organic matter to produce carbon dioxide, water, heat and
20 a humus material called "compost". Compost is a useful soil amendment which
can improve texture, air circulation and drainage while suppressing weed
growth and plant pathogens. The use of high quality compost has proven to be
a valuable tool in the quest for sustainable agriculture and horticulture.
Compost can also safely be used in landfill or land reclamation projects.

25 The quality of compost produced by the composting process, in
particular its composition, stability and odour, is largely dependent on the ability
to control oxygen level, temperature and moisture during the process. For
example, low oxygen level and low oxygen circulation inhibit aerobic
decomposition and increase anaerobic decomposition which is slower and is
30 accompanied by an unpleasant odour, whereas, low moisture and excessive
temperatures inhibit microbial activity leading to an unstable product.

There is accordingly a need for an effective and economical composting process, and device for conducting the process, which overcome, or at least alleviate, one or more disadvantages of the prior art.

5 SUMMARY OF THE INVENTION

According to the present invention, there is provided a controllable process for composting waste material including the steps of:

placing said waste material into an automatically controllable composting environment;

10 subjecting said waste material to a composting process;

periodically measuring the value of one or more parameters of the composting environment, said parameters being selected from the group including temperature, pressure, moisture content and gas composition;

15 comparing the or each measured value with a pre-determined setpoint or setpoint range; and

automatically adjusting the or each parameter, if necessary, such that the measured value of said one or more parameters agree with said setpoint or setpoint range.

20 The present invention also provides a device for carrying out controlled composting of waste material, said device including:

a closeable chamber for receiving said waste material, said chamber forming a controllable composting environment;

25 one or more sensors for measuring the value of one or more parameters of the composting environment, said parameters being selected from the group including temperature, pressure, moisture content and gas composition;

means for comparing the or each measured value with a predetermined setpoint value or setpoint range; and

30 adjustment means for automatically adjusting the or each parameter, if necessary, such that the measured value of said one or more parameters agree with said setpoint value or setpoint range.

It has been found that the effectiveness of the composting process can also be dependent on the properties of the waste material itself. Table 1 lists

examples of waste materials and their properties, which may be used in the present invention.

One such property is the average particle size of the waste material. The particle size can affect moisture retention and air circulation throughout the waste material. It has been found that an average particle size of less than 10 cm is advantageous. Preferably, the particle size is 7.5 cm or less, more preferably less than 5 cm.

Another such property is the ratio of carbon to nitrogen in the waste material. The C:N ratio is determined as an average value over all the constituents of the waste material. It is preferably within the range of from 20:1 to 40:1. A more preferred range is from 25:1 to 35:1, such as approximately 30:1. Table 1 can be used to optimise the C:N ratio of waste material. By knowing the relative proportions and C:N ratio of each component of the waste material, the overall C:N ratio may be determined.

The moisture content of the waste material is another property typically affecting the effectiveness of the composting process. At the commencement of the process, the waste material may be saturated with water, i.e. having a moisture content of around 100%. The moisture content typically decreases over time, however, as the temperature inside the device increases and moisture containing air is vented to the outside. Preferably, the moisture content of the waste material is maintained in the range of 10 to 70 wt% H₂O. More preferably, the moisture content is from 10 to 50 wt%, even more preferably from 15 to 35 wt%. The optimum moisture content is around 25 wt%.

Other physicochemical conditions can also affect the composting process.

The temperature of the composting environment can influence the quality of compost produced. It is preferred that the temperature is maintained within the range 50 to 70°C, more preferably within the range 55°C to 65°C, at least for the first approximately three days of the composting process. During this period, the compost typically undergoes pasteurisation and accordingly effective temperature control is highly desirable. After the pasteurisation stage

has completed, temperature control is less important and temperature may accordingly be allowed to decrease below the preferred range.

Oxygen concentration in the gaseous atmosphere of the composting environment can also be an important consideration. Typically, the oxygen containing gas which is used in the process and device of the invention is air. Accordingly, the maximum likely concentration of oxygen in the gas is that of air, namely around 21%. While higher concentrations may be used, they may be disadvantageous because of increased cost and/or the risk of ignition and fire. The lower limit of oxygen concentration is typically 10%. Preferably the lower limit is 15%.

The pressure of the composting environment is preferably maintained at close to atmospheric pressure. While pressure is not crucial to the composting process, it can be an important consideration with regard to prevention of "blow out", as will be discussed in greater detail subsequently.

The individual constituents of the waste material are typically selected from a range of different organic materials. Of primary interest amongst these are vegetative materials, especially leaves and wood, such as in the form of wood chips. Such vegetative materials are advantageous due to their relatively high C:N ratio, their particle size and their moisture retention properties.

Wood chips typically have an average C:N ratio of from about 100:1 to about 500:1, whereas leaves have an average C:N ratio of from about 30:1 to about 80:1. It is therefore preferred that the waste material further includes components which are relatively richer in nitrogen so as to decrease the C:N ratio of the compost to a value within the desired range. Preferred nitrogen rich materials include animal derived waste, such as manure or animal bodies or parts thereof. Such animal derived waste is herein collectively referred to as "biosolids". Animal manure, such as chicken manure, typically has a C:N ratio of between 5:1 to 25:1.

In the combined waste material, wood chips act as a rich source of carbon as well as a bulking agent. They also absorb and substantially retain moisture from the biosolids, modify porosity of the mixture and facilitate efficient circulation of air throughout the waste material.

In the process and apparatus of the invention, the automatically controllable composting environment is preferably provided by a closeable container constructed from a suitable material preferably an insulating material. Suitable materials include metal (e.g. stainless steel or aluminium), fibreglass or concrete. The size of the container will be determined according to the anticipated volume of waste which is to be composted. However, it is preferred that the height of the container does not exceed 3 metres so as to allow proper aeration of the waste materials during composting.

The container typically includes one or more side walls and a base. It preferably also includes a top wall, which may be integral with the rest of the container, or separable. The top wall may comprise a sheet of flexible material, such as a tarpaulin, made from canvas or plastics material, which is secured in place, such as by rope or ties. The base is preferably liquid and gas permeable. Preferably a cavity or gap is provided below at least a portion of the base. This may be provided by elevating the base with respect to the ground level below the container.

Where the container includes one or more flexible walls (e.g. a tarpaulin top wall), it is desirable to monitor and control the internal pressure within the container. If the internal pressure significantly exceeds atmospheric pressure, it may cause "blow out", i.e. the internal pressure may cause the flexible wall to become unsecured from the rest of the container, thereby exposing the compost to the external environment and potentially adversely affecting the composting process. To avoid excessive build-up of pressure inside the container, it is preferably provided with one or more relief valves.

The container preferably also includes at least one inlet, through which air or other oxygen containing gas may be introduced into the container. Preferably, air is forced into the container under pressure, such as by using an air compressor. The inlet(s) is preferably closeable, such as with a valve. Preferably the container also includes at least one outlet through which gases inside the container may be vented. The outlet(s) is also preferably closeable such as with a valve or a flap.

The container also preferably includes one or more sensors for measuring physiochemical conditions therein during the composting reaction.

Typically such sensors include a temperature sensor (e.g. thermometer), and an oxygen sensor. The container may also include a pressure sensor and a humidity sensor.

The container also preferably includes circulation means, typically a fan, which is used to force circulation of oxygen containing gas (preferably air) through the waste material during the composting process. Typically the circulation means is positioned so as to force the oxygen containing gas underneath the elevated base of the container such that the gas passes up through the permeable base and through the waste material where oxygen is used in the composting reactions. Gases which have been passed through the waste material may either be vented to outside the container via an outlet, or be recirculated through the permeable base for further reaction with the waste material, or to maintain a desired temperature within the container.

The container further includes one or more sensors for measuring the values of one or more parameters of the composting environment, the parameters being selected from the group including temperature, pressure, moisture content (e.g. humidity) and gas composition. The measured values of the one or more parameters are then automatically compared with a predetermined setpoint value or setpoint range. Typically, this requires that the measured value/s are fed as input into an active feedback regulatory computer programme, such as that commercially available under the trade name "CITEC", or that written by applicant and called "Compostwise" where they are compared with the predetermined setpoint value or range. If the measured value agrees with the setpoint value or falls within the setpoint range, no modification of the environmental conditions within the container are necessary. On the other hand, if the measured value/s differ from the setpoint/s, the computer programme automatically adjusts the environmental conditions as appropriate in order to bring the measured and setpoint value/s into agreement.

The following description provides examples of operation of the computer programme in response to various environmental conditions within the container.

Temperature

Where the measured temperature is less than the setpoint, the oxygen containing gas is continually recirculated through the composting waste material without introduction of cooler, ambient gas. This ensures that heat produced by exothermic reactions taking place during the composting process (i.e. the "thermophilic" composting stage) is allowed to build up to the optimum level.

On the other hand, if the thermophilic composting stage is completed, and/or the temperature has exceeded the setpoint, recirculation of oxygen containing gas is stopped and instead cooler (typically ambient) air is admitted through one or more gaseous inlets. Typically, one or more gaseous outlets are also opened to allow gas heated by the thermophilic stage to vent to the outside.

Oxygen Level

If the oxygen level in the container falls below the setpoint, oxygen containing gas (typically ambient air) is admitted through one or more inlets to induce aerobic conditions in the container. If desired, recirculation of some heated gas can be maintained at the same time in order to avoid a drop in temperature.

Pressure

If the atmospheric pressure within the container exceeds the setpoint, excess gas can be vented to outside by opening an outlet. The need to vent excess gas is greater where the top wall of the container is provided by a flexible covering, such as a plastic canvas. The outlet may be closeable by a hinged flap which is operable to open once the pressure inside the container exceeds the setpoint.

Moisture

If the moisture level in the waste materials falls below a setpoint, a humidifier can be operated so as to impart a greater water level to the oxygen containing gas. Typically, the humidifier is positioned at or near an inlet for oxygen containing gas, and is preferably located downstream of the circulation means.

As previously mentioned, a circulation means is preferably employed to circulate the oxygen containing gas throughout the container. Preferably the circulation means is a fan, more preferably a multi-speed fan such that fine tuning of the physicochemical conditions within the container can be effected by varying the speed of the fan.

As previously mentioned, the base of the container is preferably liquid permeable as well as gas permeable, so as to allow liquids (hereinafter called "leachate") from the waste material charge to pass therethrough. The permeable base is preferably elevated above the ground level beneath the container. Preferably collecting means are provided below the permeable base for collecting leachate which passes therethrough. The collecting means preferably includes an inclined surface (such as a vessel having an inclined floor) such that leachate flows down the inclined surface under the influence of gravity. The collecting means may also have an outlet through which leachate may leave the container and be discarded or retained for further processing as a liquid compost.

Waste materials may be loaded into the inventive device either manually, or automatically such as by using a FM (frequency modulated) controlled conveyor belt system. The homogeneity and relative proportions of constituents making up the waste material may be controlled efficiently by using a loaded cell housing which feeds to a mixing unit. In such a manner, each mixture of waste materials may be prepared according to a predetermined "recipe". Furthermore, to ensure thorough mixing of the constituents, a multi auger blender can be used.

The particle size and texture of the fresh compost produced by the invention can be optimised by subjecting it to grinding and screening. Preferably, the fresh compost is subjected to a high speed hammer mill shredder and then a rotary trommel screen. Large compost particles may then be returned to the inventive device to go through the composting process again.

After optimisation of the particle size and texture of the compost, the compost preferably undergoes maturation, a process in which the fresh compost cools and matures so as to improve the quality of the compost. This

may be preferably conducted in open windrows in which the compost is piled up and turned over periodically (e.g. once a week) for aeration.

The optimisation of composting conditions via the present invention provides a homogeneous environment for naturally occurring microorganisms to convert solid waste into an organic compost. Moreover, the prolonged heating of the waste material concurrently pasteurises the compost and ensures that the compost is essentially free of pathogens and weeds.

The composting process and device of the present invention can advantageously accelerate natural aerobic composting of waste material by up to a factor of five. The present invention can accordingly reduce a normally five week thermophilic stage of a composting process into approximately one week. Furthermore, due to the aerobic conditions maintained within the container, the odour level is minimised due to production of oxidised gases such as H_2O and CO_2 , instead of anaerobic gases such as methane, ammonia and hydrogen sulphide. These features mean that the present invention is ideally suited to recycling of waste in confined areas and in close proximity to sensitive receptors.

Moreover, the present invention may be used for the remediation of hazardous waste, like oily sludge, tank bottoms and hydrocarbon-contaminated soils. Further, due to the leachate collection means, the process can also be used for composting liquid waste, such as soft drinks which are rich in materials like phosphorus and sugar.

Virtually any type of biosolids may be used in the inventive process, as long as the waste materials are adequately mixed and preferably have the desired C:N ratio.

DESCRIPTION OF THE DRAWING

Figure 1 is a schematic cross-section of a composting device according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention will become more readily apparent from the following exemplary description in connection with the accompanying drawing and Example.

5 Referring to Figure 1, there is illustrated a composting device 10 comprising a closeable container 12 constructed from (?) stainless steel. Inside the container 12 is defined an automatically controllable composting environment 14. The container 12 includes a side wall 16, a top wall 17 and an elevated, gas and liquid permeable base 18, which supports the waste material
10 (not shown).

The container 12 is provided with an inlet 20 through which oxygen containing gas comprising compressed, ambient air may be introduced into the container 12. The inlet 20 is operable by a valve 22 by which the flow of ambient air into the container 12 may be controlled.

15 The container 12 is also provided with an outlet 24 through which gas may exit the container 12. The flow of gas through the outlet 24 is controlled by a valve 26.

The container 12 further includes one or more sensors comprising a temperature sensor 28 and an oxygen sensor 30 for measuring the
20 temperature and oxygen content, respectively, of the composting environment 14.

Air circulation means comprises a multi-speed fan 32 located downstream of the air inlet 20. Downstream from the fan 32 is provided a humidifier 34 which acts to increase the moisture content of the air entering the
25 container 12.

Below the permeable base 18 is a leachate collecting means comprising a vessel 36 which includes an inclined surface, namely the vessel floor 38. Leachate which passes through the base 18 flows down the inclined surface under the influence of gravity. At the lowermost point of the vessel floor 38 is
30 provided a leachate outlet 40 through which the leachate may leave the container and be discarded or retained for further processing.

The control of the physicochemical conditions inside container 12 will now be described.

The temperature of the composting environment 14 is measured by the temperature sensor 28 and the measured value is fed to a computer programme (not shown). If the measured temperature is less than a predetermined setpoint, in this case 58°C, valves 22 and 26 are closed and valve 42 is opened. This ensures that air inside the container travels through fan 32 such that it enters vessel 36 in the direction of the arrows, travels up through the permeable base 18 and through the waste material, then back via sensors 28 and 30 and recirculated back to the fan 32 via conduit 44. Heat generated by exothermic reactions taking place during the composting process (i.e. the "thermophilic" stage) is allowed to increase until the temperature of the composting environment reaches the setpoint (again, in this case, 58°C).

When the temperature has exceeded the setpoint (i.e. 58°C), valve 42 is closed and valves 22 and 26 are opened, thereby stopping the recirculation of heated air and drawing in cooler ambient air.

If the oxygen level sensed by oxygen sensor 30 falls below the setpoint value (in this case 15%), valves 22 and 26 are opened to draw in oxygen rich air from outside, thereby inducing aerobic conditions. In order to avoid or minimise a drop in temperature, the valve 42 can also be kept open, thereby allowing some recirculation of heated air.

If the pressure sensor 31 measures a pressure inside the container 12 that exceeds a setpoint (in this case at atmospheric pressure) excess gas can be vented to the outside either by opening valve 26, or opening a flap 46.

EXAMPLE

A waste composition of 16 wt% chicken manure and 84 wt% woodchips were mixed together and placed into a composting device in accordance with Figure 1. The composting device was thermally insulated and included a water reservoir downstream of the air compressor in order to hydrate air entering the device. The temperature of the composting environment reached greater than 60°C within the first 12 hours until feedback from the temperature probe reduced the temperature to close to the setpoint of 58°C. The thermophilic composting process lasted for five days. The resulting composted material

appeared to be well blackened and the entire process had minimal or no odour generation.

Finally, it is to be understood that various alterations, modifications and/or additions may be introduced into the constructions and arrangements of parts and/or steps previously described without departing from the spirit or
5 ambit of the invention. It should be also understood that the foregoing description of the invention is not intended to be limiting, but is only exemplary of the inventive features which are defined in the following claims.

CLAIMS:

1. A controllable process for composting waste material including the steps of:

5 placing said waste material into an automatically controllable composting environment;

subjecting said waste material to a composting process;

periodically measuring the value of one or more parameters of the composting environment, said parameters being selected from the group including temperature, pressure, moisture content and gas composition;

10 comparing the or each measured value with a pre-determined setpoint or setpoint range; and

automatically adjusting the or each parameter, if necessary, such that the measured value of said one or more parameters agrees with said setpoint or setpoint range.

2. The process of claim 1, wherein said one or more parameters includes the temperature of the composting environment and said predetermined setpoint range is from 50°C to 70°C, preferably from 55°C to 65°C.

20 3. The process of claim 2, wherein said step of automatically adjusting is carried out for a period of at least three days after commencement of said composting process.

4. The process of any one of claims 1 to 3, wherein said one or more parameters includes the gas composition of the composting environment, preferably oxygen concentration.

5. The process of claim 4, wherein the oxygen concentration is greater than 10%, preferably between about 15% and 21%.

6. The process of any preceding claim, wherein the pressure of the composting environment is close to atmospheric pressure.

7. The process of any preceding claim, wherein the measured value of said one or more parameters is fed as input into an active feedback regulatory computer programme, which compares the measured value with said setpoint or setpoint range and automatically adjusts each parameter, if necessary, until
5 the measured value agrees with said setpoint or setpoint range.

8. The process of any preceding claim, wherein the ratio of carbon to nitrogen (C:N) in the waste material is from 20:1 to 40:1, preferably from 25:1 to 35:1, more preferably about 30:1.

10 9. The process of any preceding claim, wherein the average particle size of the waste material is less than 10 cm, preferably less than 7.5 cm, more preferably less than 5 cm.

15 10. The process of any preceding claim, wherein the moisture content of the waste material is from 10 to 70 wt% H₂O, preferably from 10 to 50 wt% H₂O, more preferably more 15 to 35 wt% H₂O.

20 11. A device for carrying out controlled composting of waste material, said device including:

a closeable chamber for receiving said waste material, said chamber forming a controllable composting environment;

25 one or more sensors for measuring the value of one or more parameters of the composting environment, said parameters being selected from the group including temperature, pressure, moisture content and gas composition;

means for comparing the or each measured value with a predetermined setpoint value or setpoint range; and

30 adjustment means for automatically adjusting the or each parameter, if necessary, such that the measured value of said one or more parameters agree with said setpoint value or setpoint range.

12. The device of claim 11, wherein said closeable chamber is provided by a metal container, preferably made from aluminium or stainless steel.

13. The device of claim 12, wherein the height of the container does not exceed approximately 3 metres.

5 14. The devices of any one of claims 11 to 13, wherein said container includes one or more side walls and a base, preferably the base is gas and liquid permeable.

10 15. The device of claim 14, wherein a space is provided below at least part of said base, preferably said space is formed by elevating said base with respect to ground level below said container.

15 16. The device of any one of claims 11 to 15, further including at least one gas inlet through which oxygen containing gas is admitted to the composting environment, and at least one gas outlet.

17. The device of claim 16, wherein said oxygen containing gas is air, preferably admitted under pressure, such as by using an air compressor.

20 18. The device of claim 16, wherein said inlet and outlet are each closeable, preferably with a valve or a flap.

25 19. The device of any one of claims 11 to 18, wherein said sensors include at least a temperature sensor and an oxygen sensor.

20. The device of any one of claims 11 to 19, further including a gas circulation means, preferably comprising a fan, more preferably comprising a multi-speed fan, for circulating said oxygen containing gas through the waste material.

30 21. The device of claim 20, wherein said circulation means is positioned so that, in use, said oxygen containing gas passes from said space through said

gas permeable base and upwards through said waste material where it is used in said composting process.

22. The device of claim 21, wherein reactant gas resulting from reaction of said oxygen containing gas with said waste material, is either vented through said at least one outlet or is recirculated back through said permeable base for further reaction with said waste material.

23. The device of any one of claims 11 to 22, wherein the measured value of said one or more parameters is fed as input into an active feedback regulatory computer programme which compares the measured value with said setpoint value or setpoint range, and automatically adjusts each parameter if necessary, until the measured value agrees with said setpoint or setpoint range.

24. The device of claim 23, wherein adjustment of temperature is effected by continuously recirculating said reactant gas through said waste material, in order to increase temperature.

25. The device of claim 23, wherein adjustment of temperature is effected by continuously introducing fresh oxygen containing gas through said one or more inlets, and venting said reactant gas through said one or more outlets.

26. The device of claim 23, wherein adjustment of oxygen concentration is effected by introducing fresh oxygen containing air through said one or more inlets to increase oxygen concentration.

27. The device of any one of claims 14 to 26, wherein a collecting means is provided beneath the permeable base for collecting leachate.

28. The device of claim 27, wherein said collecting means includes an inclined surface, such that said leachate flows down the inclined surface under the influence of gravity, to an outlet through which said leachate may leave the container.

TABLE 1

Material	Type of Value	% N (dry weight)	C:N ratio (weight to weight)	% C (dry weight)	Moisture content % (wet weight)	Bulk Density (pounds per cubic yard)
Crop residues and fruit/vegetable-processing wastes						
Apple filter cake	Typical	1.2	13	15.6	60	1,197
Apple pomace	Typical	1.1	48	52.8	88	1,559
Apple-processing sludge	Typical	2.8	7	19.6	59	1,411
Cocoa shells	Typical	2.3	22	50.6	8	798
Coffee grounds	Typical	-	20		-	-
Corn cobs	Range	0.4-0.8	56-123	22.4-98.4	9.0-18.0	-
	Average	0.6	98	58.8	15	557
Corn stalks	Typical	0.6-0.8	60-73 a	36-58.4	12	32
Cottonseed meal	Typical	7.7	7	53.9	-	-
Cranberry filter cake	Typical	2.8	31	86.8	50	1,021
(with rice hulls)	Typical	1.2	42	50.4	71	1,298
Cranberry plant (stems, leaves)	Typical	0.9	61	54.9	61	-
Cull potatoes	Typical	-	18		78	1,540
Fruit Wastes	Range	0.9-2.6	20-49	18-127.4	62-88	-
	Average	1.4	40	56	80	-
Olive husks	Typical	1.2-1.5	30-35	36-52.5	8.0-10.0	-
Potato-processing sludge	Typical	-	28		75	1,570
Potato tops	Typical	1.5	25	37.5	-	-
Rice hulls	Range	0-0.4	113-1120	0-100	7.0-10.0	185-219
	Average	0.3	121	36.3	14	202
Soybean meal	Typical	7.2-7.6	4.0-6.0	28.8-45.6	-	-
Tomato-processing waste	Typical	4.5	11 ^a	49.5	62	-
Vegetable produce	Typical	2.7	19	51.3	87	1,585
Vegetable wastes	Typical	2.5-4	11.0-13.0	27.5-52	-	-
				0		
Fish and meat processing						
Blood wastes (slaughterhouse waste and dried blood)	Typical	13-14	3-3.5	39-49	10.0-78.0	-
				0		
Crab and lobster wastes	Range	4.6-8.2	4.0-5.4	18.4-44.3	35-61	-
	Average	6.1	4.9	29.89	47	240
Fish-breeding crumbs	Typical	2	28	56	10	-
Fish-processing sludge	Typical	6.8	5.2	35.36	94	-
Fish wastes (gurry, racks, and so on)	Range	6.5-14.2	2.6-5.0	16.9-71	50-81	-
	Average	10.6	3.6	38.16	76	-
Mixed slaughterhouse waste	Typical	7.0-10.0	2.0-4.0	14.0-40.0	-	-
Mussel wastes	Typical	3.6	2.2	7.92	63	-
Poultry carcasses	Typical	2.4 b	5	12	65	-
Paunch manure	Typical	1.8	20-30	36-54	80-85	1,460
Shrimp wastes	Typical	9.5	3.4	32.3	78	-

Manures						
Broiler litter	Range	1.6-3.9	12-15 a	19.2-58.5	22-46	756-1,026
	Average	2.7	14 a	37.8	37	864
Cattle	Range	1.5-4.2	11.0-30.0	16.5-100	67-87	1,323-1,674
	Average	2.4	19	45.6	81	1,458
Dairy tie stall	Typical	2.7	18	48.6	79	-
Dairy free stall	Typical	3.7	13	48.1	83	-
				0		
Horse-general	Range	1.4-2.3	22-50	30.8-100	59-79	1,215-1,620
	Average	1.6	30	48	72	1,379
Horse-race track	Range	0.8-1.7	29-56	23.2-100	52-67	-
	Average	1.2	41	49.2	63	-
Laying hens	Range	4.0-10.0	3.0-10.0	12.0-100	62-75	1,377-1,620
	Average	8	6	48	69	1,479
Sheep	Range	1.3-3.9	13-20	16.9-78	60-75	-
	Average	2.7	16	43.2	69	-
Swine	Range	1.9-4.3	9.0-19.0	17.1-81.7	65-91	-
	Average	3.1	14	43.4	80	-
Turkey litter	Average	2.6	16	41.6	26	783
Municipal wastes						
Garbage (food waste)	Typical	1.9-2.9	14-16	26.6-46.4	69	-
Night soil	Typical	5.5-6.5	6.0-10.0	33.0-65.0	-	-
Paper from domestic refuse	Typical	0.2-0.25	127-178	25.4-44.5	18-20	-
Pharmaceutical wastes	Typical	2.6	19	49.4	-	-
Refuse (mixed food, paper, and so on)	Typical	0.6-1.3	34-80	20.4-100	-	-
Sewage sludge	Range	2-6.9	5.0-16.0	10.0-100.0	72-84	1,075-1,750
Activated sludge	Typical	5.6	6	33.6	-	-
Digested sludge	Typical	1.9	16	30.4	-	-
Straw, hay, silage						
Corn silage	Typical	1.2-1.4	38-43 a	45.6-60.2	65-68	-
Hay-general	Range	0.7-3.6	15-32	10.5-100	8.0-10.0	-
	Average	2.1	23.5	49.4	-	-
Hay-legume	Range	1.8-3.6	15-19	27.0-68.4	-	-
	Average	2.5	16	40	-	-
Hay-non-legume	Range	0.7-2.5	-	-	-	-
	Average	1.3	32	41.6	-	-
Straw-general	Range	0.3-1.1	48-150	14.4-100	4.0-27.0	58-378
	Average	0.7	80	56	12	227

Straw-oat	Range	0.6-1.1	48-98	28.8-100	-	-
	Average	0.9	60	54	-	-
Straw-wheat	Range	0.3-0.5	100-150	30.0-75.0	-	-
	Average	0.4	127	50.8	-	-
Wood and paper						
Bark-hardwoods	Range	0.10-0.41	116-436	11.6-100	-	-
	Average	0.241	223	53.743	-	-
Bark-softwoods	Range	0.04-0.39	131-1,285	5.24-100	-	-
	Average	0.14	496	69.44	-	-
Corrugated cardboard	Typical	0.1	563	56.3	8	259
Lumbermill waste	Typical	0.13	170	22.1	-	-
Newsprint	Typical	0.06-0.14	398-852	23.9-100	3.0-8.0	195-242
Paper fiber sludge	Typical	-	250		66	1140
Paper mill sludge	Typical	0.56	54	30.24	81	-
Paper pulp	Typical	0.59	90	53.1	82	1403
Sawdust	Range	0.06-0.8	200-750	12.0-100	19-65	350-450
	Average	0.24	442	106.08	39	410
Telephone books	Typical	0.7	772	540.5	6	250
Wood chips	Typical	-	-		-	445-620
Wood-hardwoods (chips, shavings, and so on)	Range	0.06-0.11	451-819	27.06-90.0	-	-
	Average	0.09	560	50.4	-	-
Wood-softwoods (chips, shavings, and so on)	Range	0.04-0.23	212-1,313	8.48-100	-	-
	Average	0.09	641	57.69	-	-
Yard wastes and other vegetation						
Grass clippings	Range	2.0-6.0	9.0-25.0	18.0-100	-	-
	Average	3.4	17	57.8	82	-
Loose	Typical	-	-		-	300-400
Compacted	Typical	-	-		-	500-800
Leaves	Range	0.5-1.3	40-80	20.0-100.0	-	-
	Average	0.9	54	48.6	38	-
Loose and dry	Typical	-	-		-	100-300
Compacted and moist	Typical	-	-		-	400-500
Seaweed	Range	1.2-3.0	5.0-27.0	6.0-81.0	-	-
	Average	1.9	17	32.3	53	-
Shrub trimmings	Typical	1	53	53	15	429
Tree trimmings	Typical	3.1	16	49.6	70	1,296
Water hyacinth-fresh	Typical	-	20-30		93	405