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Greene

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(54) **SYSTEM AND PROCESS FOR TREATING WASTE WATER**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

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(22) Filed: **Sep. 12, 2000**

Related U.S. Application Data

(63) Continuation-in-part of application No. 09/320,904, filed on May 27, 1999, now Pat. No. 6,117,324.

(51) **Int. Cl.**⁷ **C02F 3/30**

(52) **U.S. Cl.** **210/192; 210/220; 210/760; 261/77; 261/DIG. 42**

(58) **Field of Search** **210/167, 172, 210/192, 194, 220, 760, 627, 631, 916; 261/77, DIG. 42**

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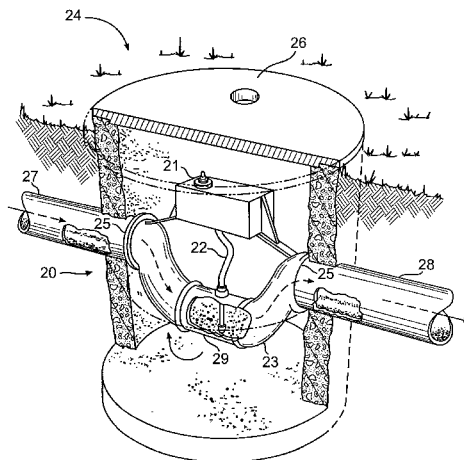
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(57) **ABSTRACT**

The present invention is generally directed to a process and system for treating animal waste. More particularly, the present invention is directed to a process and system for treating animal waste effluent with ozone to decompose the organic material within and improve the odor of the animal waste. The process of the present invention also reduces biochemical oxygen demand, chemical oxygen demand, total bacterial content and coliform bacterial count of the animal waste. The process of this present invention comprises collecting an animal waste solution, containing a mixture of water and animal fecal material; contacting the waste solution with ozone in an amount sufficient to oxidize at least a portion of the organic material contained within; and feeding the ozone treated waste solution to a solids separating device prior to collecting the waste solution in a biobasin or, alternatively, recycling the ozone treated waste solution for use as a source of irrigation or flushwater.

19 Claims, 6 Drawing Sheets



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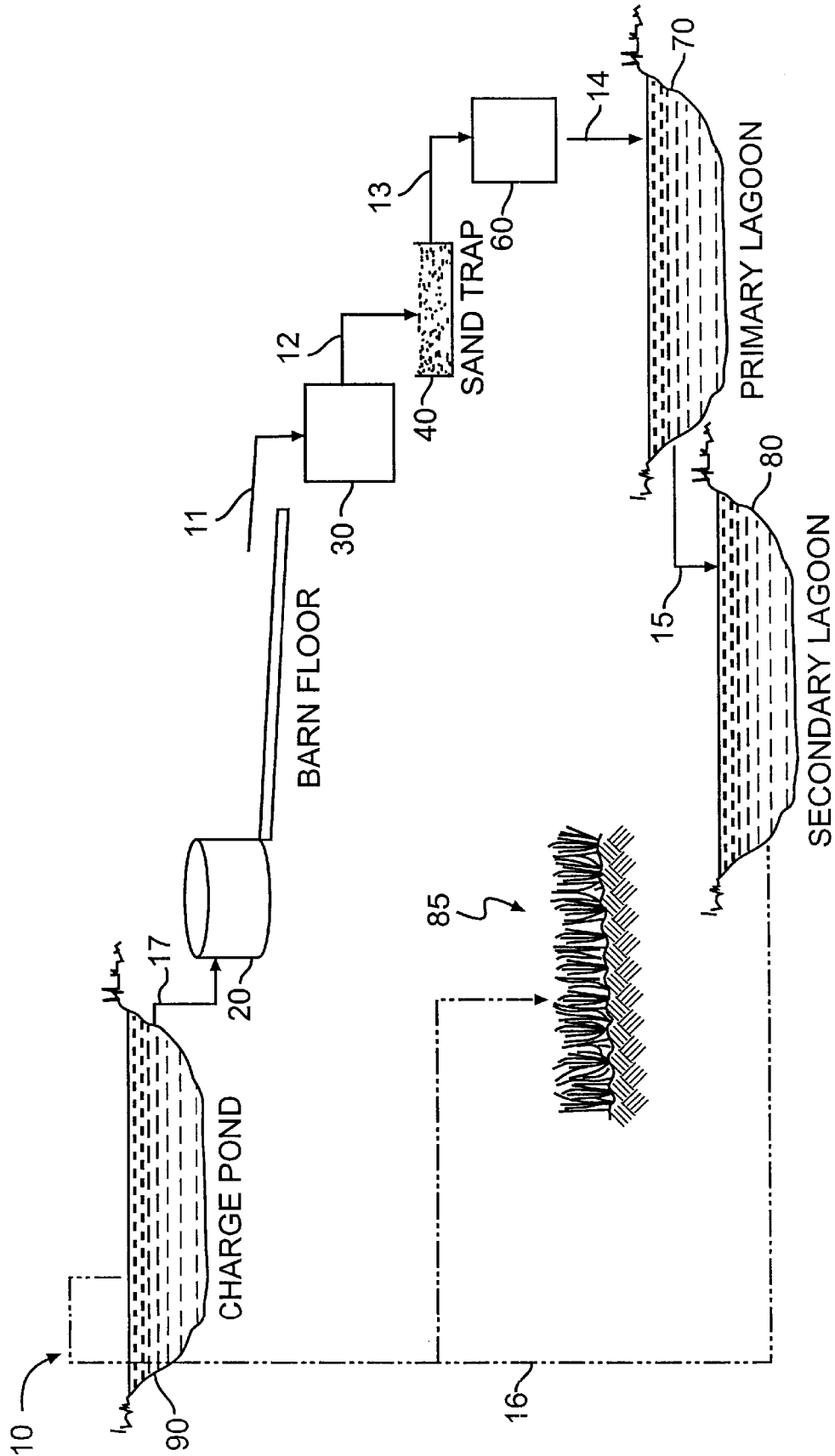


FIG. 1

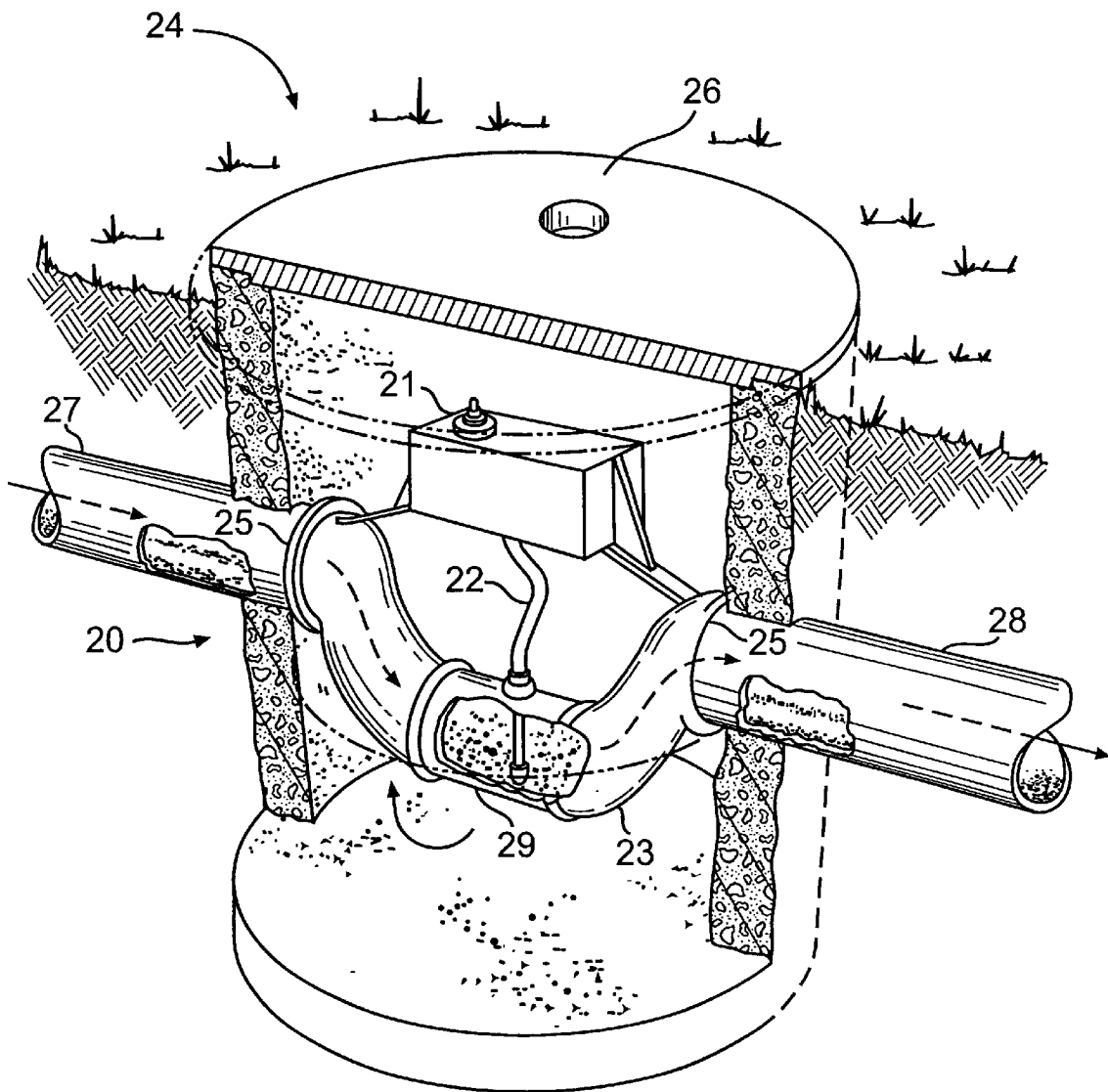
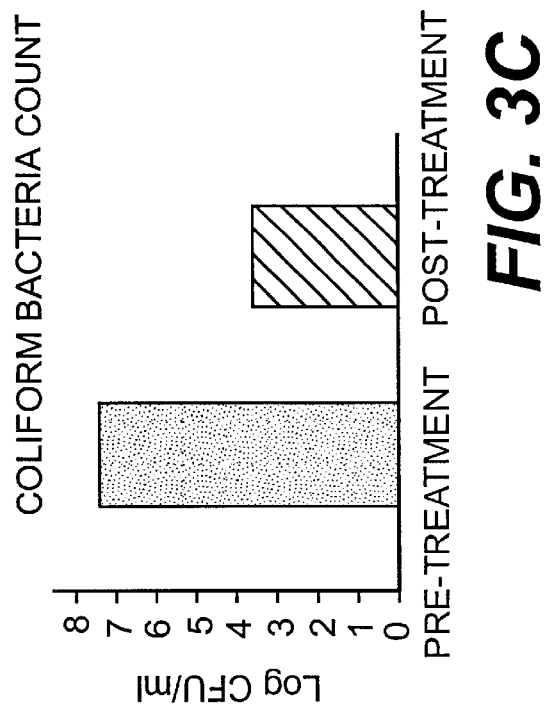
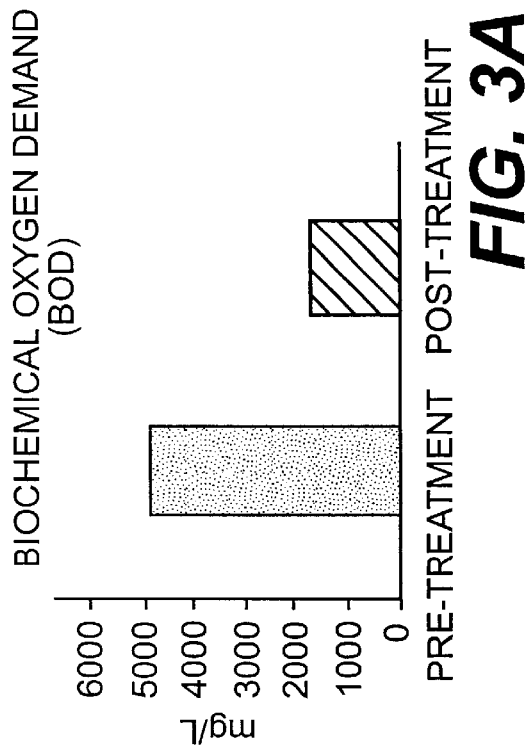
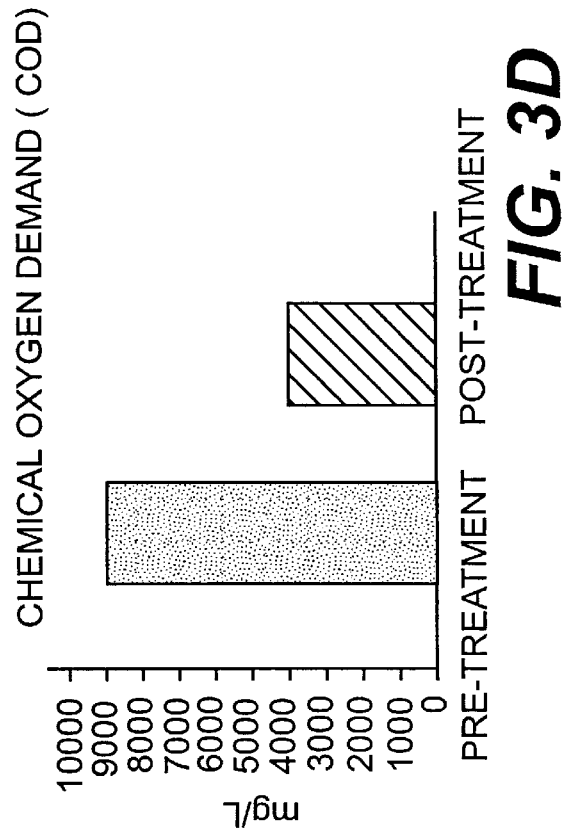
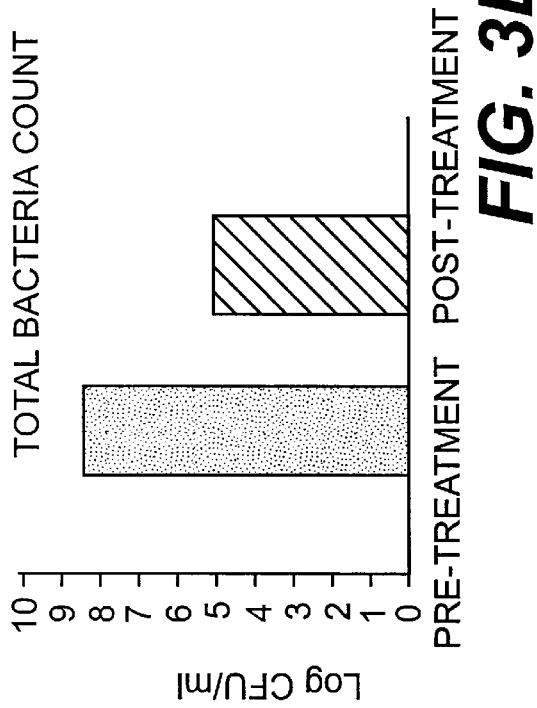


FIG. 2



REVERSE PHASE HPLC ANALYSIS OF ODORIFEROUS MANURE COMPONENTS

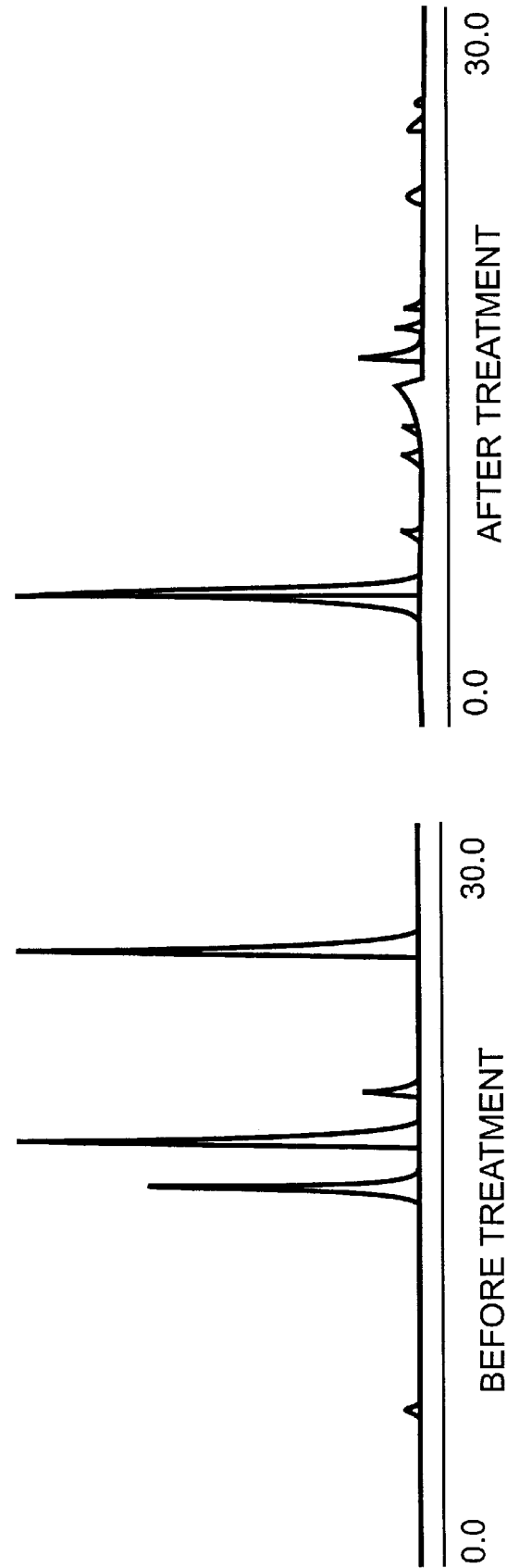


FIG. 4

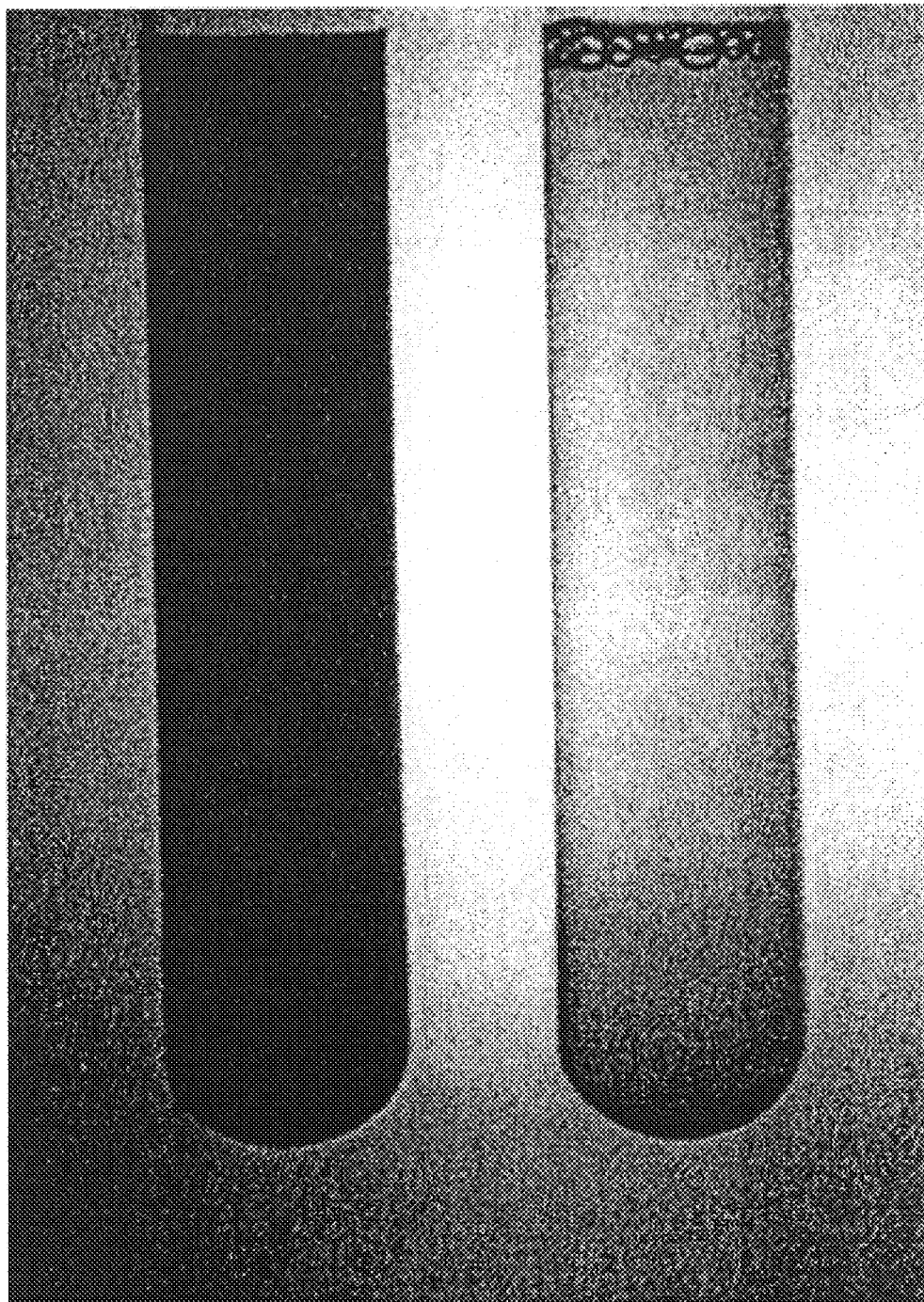


FIG. 5

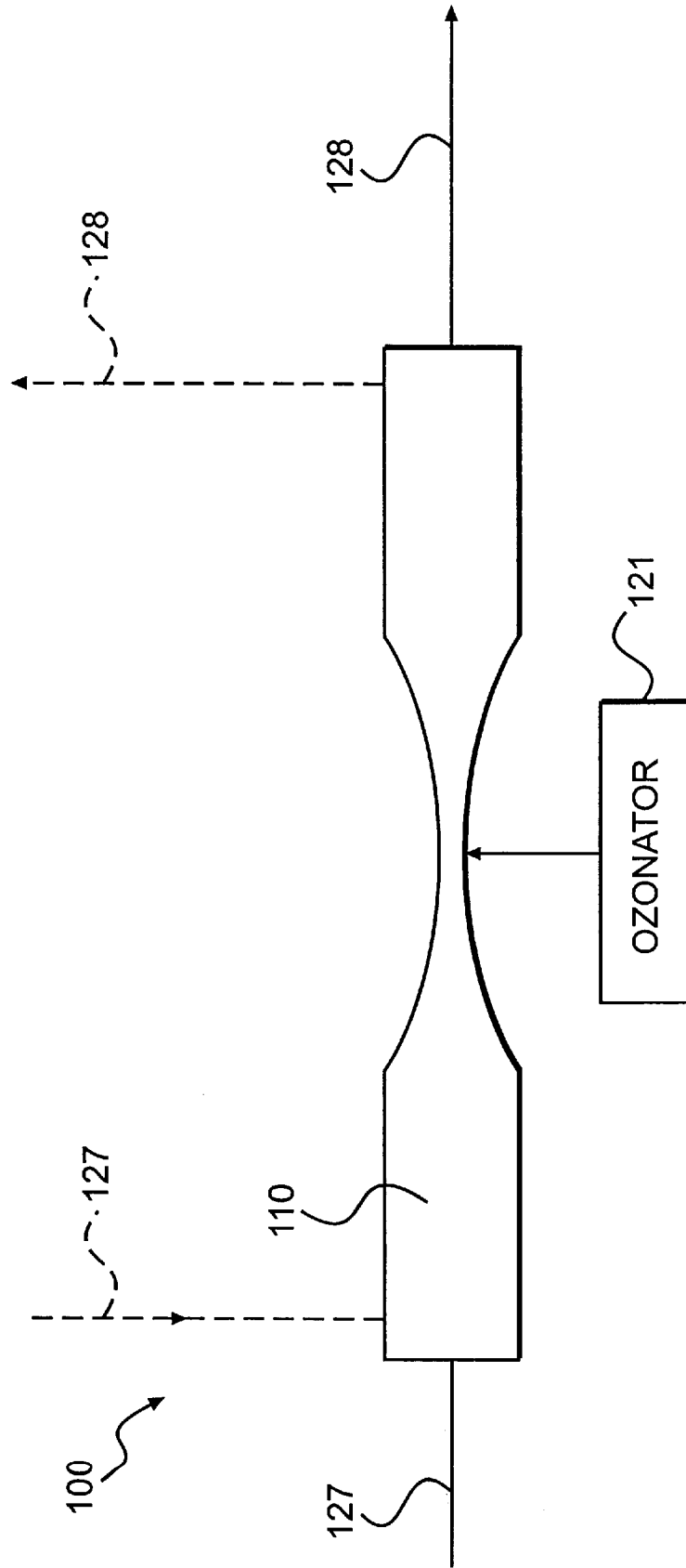


FIG. 6

SYSTEM AND PROCESS FOR TREATING WASTE WATER

This application is a continuation in part of U.S. application Ser. No. 09/320904, filed May 27, 1999, now U.S. Pat. No. 6,117,324. 5

FIELD OF THE INVENTION

The present invention is generally directed to a process and system for treating waste water. More particularly, the present invention is directed to a process and system for treating an effluent with ozone to decompose the organic material within, sufficiently reduce microorganisms within, and improve the odor of the liquid. 10

BACKGROUND OF THE INVENTION

One major dilemma plaguing farmers who raise livestock and/or poultry is the ability to efficiently neutralize and dispose of animal waste. Left untreated, animal waste is a significant health and environmental hazard. Animal waste creates a public nuisance because of its odor, and improper disposal is associated with significant problems such as water contamination. 20

In the past, animal waste was typically collected and channeled to a pond or lagoon. Before being emptied into the lagoon, the animal waste may or may not have been separated via mechanical means in order to remove various particulate matter such as sediment. Once fed to the pond or lagoon, the animal waste came in contact with various microorganisms and underwent biodegradation. 25

Prior art systems, however, have various deficiencies and drawbacks. In particular, these systems did little to initially improve the odor of the waste. Typically, odors originating from the animal waste were only improved or reduced over a substantial amount of time. 30

Further, these systems tended to work very slowly and would completely fail under some environmental conditions. For instance, under stagnant and hot conditions, the pond or lagoon would fail to adequately biodegrade the waste, overloading the system and creating a very unfavorable situation. Continued deposit of waste into the overloaded system would result in reduced growth or death of the microorganisms responsible for biodegradation. 35

As such, a need currently exists for an improved system and process for treating animal waste. In particular, a need currently exists for a process that can safely treat animal waste very rapidly to immediately reduce or otherwise improve the odor that is given off by the waste. A need also exists for a system and process that can very quickly reduce BOD, COD, total bacterial count, and the total coliform count present in animal waste. 40

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a process and system for treating animal waste. 45

Another object of the present invention is to provide a process for treating liquid waste to improve the odor associated with the liquid waste.

Yet another object of the present invention is to provide a process for treating animal waste comprising contacting the animal waste solution with ozone in an amount sufficient to oxidize and decompose organic matter contained in the animal waste solution. 50

Yet a further object of the present invention is to provide a system and process to treat animal waste such that BOD,

COD, total bacterial content and the coliform content of the waste are substantially reduced.

These and other objects of the present invention are achieved by providing a system and process for treating animal waste. The process includes the steps of collecting an animal waste solution containing a mixture of water and animal fecal matter and contacting the animal waste solution with ozone in an amount sufficient to oxidize organic matter contained in the animal waste solution. Specifically, the process for treating animal waste is capable of improving the odor associated with the animal waste. The process of the present invention also reduces BOD, COD, total bacterial content and the coliform content associated with the animal waste. By partially oxidizing the organic matter in route to a lagoon, the process of the present invention makes the organic matter more readily biodegradable and utilizable by the microflora in the lagoon. 15

BRIEF DESCRIPTIONS OF THE FIGURES

A full and enabling disclosure of the present invention, includes reference to the accompanying figures, in which:

FIG. 1 is a diagrammatical view of an animal waste system made in accordance with the present invention;

FIG. 2 is a diagrammatical view illustrating an in-line ozonation device made in accordance with the present invention;

FIG. 3(a) is a graph illustrating the results of biochemical oxygen demand (BOD) and pretreatment waste solution as compared to post treatment waste solution;

FIG. 3(b) is a graph illustrating the total aerobic bacterial count of the pretreatment waste solution compared to waste solution treated in accordance with the present invention;

FIG. 3(c) is a graph illustrating the coliform bacteria count in pretreatment waste as compared to waste treated in accordance with the present invention;

FIG. 3(d) is a graphic illustration of the chemical oxygen demand (COD) in pretreated waste versus waste treated in accordance with the present invention;

FIG. 4 illustrates reverse phase HPLC analysis of odoriferous manure components in a solution before treatment, as compared to a solution after treatment in accordance with the present invention;

FIG. 5 is a photograph illustrating the appearance of pretreatment waste solution as compared to waste treated in accordance with the present invention; and

FIG. 6 is an alternative embodiment of in-line ozonation device made in accordance with the present invention. 50

Repeat use of reference characters in the present specification and drawings is intended to represent same or analogous features of the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

Other objects, features and aspects of the present invention are disclosed in, or are obvious from, the following Detailed Description. It is to be understood by one of ordinary skill in the art that the present discussion is a description of exemplary embodiments only and is not intended as limiting the broader aspects of the present inventions which broader aspects are embodied in the exemplary construction. 55

In general, the present invention is broadly directed to a process for treating animal waste, and other malodorous wastewater. In particular, the system and process of the

present invention are directed toward treating animal waste with ozone in an amount sufficient to oxidize organic matter contained in the waste, so that the odor accompanying the animal waste is substantially reduced. Additionally, treatment of animal waste according to the present invention results in a significant reduction in the biochemical oxygen demand (BOD), chemical oxygen demand (COD), total bacteria count, and coliform bacteria count.

One presently preferred embodiment of the present invention is broadly illustrated in FIG. 1. System 10 generally comprises a barn or other animal containment area, flush tank 20, treatment chamber 30, settling device 40, solids separator 60, a first biobasin 70, a second biobasin 80, and charge pond 90. System 10 may further include conduit 11, connecting flush tank 20 to treatment chamber 30; conduit 12, connecting treatment chamber 30 to settling device 40; conduit 13, connecting settling device 40 to solids separator 60; conduit 14, connecting solids separator 60 to first biobasin 70; conduit 15, connecting first biobasin 70 to second biobasin 80; and discharge line 16, connecting second biobasin 80 to charge pond 90.

Animal facilities often use contained areas to house animals for at least a portion of the animal's growth cycle. For example, farming operations, poultry houses and livestock production facilities may segregate some, if not all, of the animals in a barn or other enclosed structure. Likewise, commercial facilities such as dog kennels may breed and house animals in an enclosed structure. Enclosed structures present a problem to the animal caretaker, however, in that excrement and other waste products such as spilled feed, must be discarded. One disposal solution is to flush the floor of the containment area with running water so as to produce an animal waste solution. The animal waste solution is subsequently flushed via a drain into a holding area. Alternately, animal waste may be collected manually and disposed of in a holding area. The animal waste solution in the holding area can be subjected to further treatment, if desired.

Referring now to FIG. 1, a system for animal waste treatment is illustrated. According to the present invention, flush tank 20 can be configured as a tank, a drum, a chamber, a cylinder, a fluid hose, a fluid pipe, or in any other shape sufficient to contain fluid within for flushing animal waste from the floor of a barn or other animal containment facility. The tank can be made of various material in accordance with the invention, such as steel, concrete, aluminum, or any other material suitable for holding fluid. The size of the tank can range from about 1 gallon to about 1,000,000 gallons depending on the size of the operation to be flushed.

In one embodiment contemplated by the present invention, flush tank 20 is associated with an ozonator to provide a source of ozone for treating contaminated water. The ozonator will be described in more detail below.

In a preferred embodiment, flush tank 20 further comprises a mechanism for rapidly releasing flush water. According to the present invention, the mechanism may include a pump sufficient to pump water from tank 20 through conduit 11 to waste treatment chamber 30. Alternately, flush water may be discharged gravitationally from flush tank 20.

In accordance with the present invention, conduit 11, connecting flush tank 20 to treatment chamber 30, may comprise a floor, a pipe, a tube, a channel or any other device suitable for safely transporting a fluid solution from a source to a receptacle. Fluid may be driven through conduit 11 as a result of force generated by a pump or, alternatively, the

fluid may be conducted through conduit 11 by gravity. Fluid flowing through conduit 11 flushes animal waste from the animal holding area to treatment chamber 30.

According to the present invention, an animal waste solution is deposited into treatment chamber 30. As described above, the waste solution comprises waste flushed from the floor of an animal containment facility by flush water from flush tank 20 and travels via conduit 11 into treatment chamber 30. In an alternative embodiment, animal waste may be collected from the animal containment area and manually deposited into treatment chamber 30, to be mixed with water from flush tank 20.

Treatment chamber 30 is configured as described above for flush tank 20. Depending upon the amount of animal waste to be treated, treatment chamber 30 ranges in size from about 1 gallon to about 1,000,000 gallons.

In accordance with the present invention, treatment chamber 30 preferably is associated with an ozonator to provide a source of ozone for waste treatment. In general, an ozonator produces ozone by, for example, applying electricity to air or oxygen resulting in ozone-enriched air. One embodiment of the present invention contemplates an ozonator comprising an ozone generator, but any device which creates ozone from air or oxygen and permits the ozone produced to contact the animal waste solution, such that the ozone reacts with animal waste constituents, is contemplated by the present invention.

As described above, the ozonator of the present invention can include a source of electricity to produce ozone from air or oxygen. Preferably, the electricity source for the ozonator comprises a photoelectric array, however, other sources of electricity useful for producing ozone from air or oxygen are contemplated by the present invention.

In a preferred embodiment, the ozonator includes multiple ports located at or near the bottom of treatment chamber 30, to permit the ozone generated by the ozonator to enter the bottom of chamber 30 to contact the animal waste solution therein.

Waste treatment chamber 30 further includes a mechanical pump, or gravitational transport configured as described above, for pumping fluid from treatment chamber 30 to settling device 40. It should be understood, however, that settling device 40 can be located prior to treatment chamber 30 in an alternative embodiment.

Conduit 12, configured as described above for conduit 11, carries post-ozonated animal waste solution from waste treatment chamber 30 to settling device 40. As contemplated by the present invention, settling device 40 may comprise a concrete pad or, alternatively, any suitable clarifier may be used which is configured to slow the flow rate of the post-ozonated waste solution and permit solids to settle out from the waste solution.

As illustrated in FIG. 1, settling device 40 comprises a concrete pad to trap sand and other sediment from the post-ozonated animal waste solution. The post-ozonated animal waste solution is conducted from settling device 40 into solids separator 60 via conduit 13. Conduit 13 is configured as described above for conduit 11. Solids separator 60 separates suspended solids from the animal waste solution, thereby decreasing the contamination of the remaining solution.

The post-ozonated animal waste solution is conducted from solids separator 60 into first biobasin 70 via conduit 14, configured as described above for conduit 11. First biobasin 70 may comprise a pond, a lagoon, a holding tank or other suitable reservoir for holding fluid. Preferably, first biobasin

70 further includes microorganisms configured to degrade or utilize organic matter within the animal waste system.

In accordance with the present invention, the waste solution from first biobasin **70** can be decanted for use in irrigation or, alternatively, conducted via conduit **15** to second biobasin **80**. Second biobasin **80** may be configured to contain additional microorganisms to degrade or utilize organic components in the waste. In yet another embodiment contemplated by the invention, the waste solution from first biobasin **70** can be recirculated to treatment chamber **30** via conduit **15**. Conduit **15** is configured as described above for conduit **11**, and may further comprise at least one valve, such that the flow of waste solution can be directed along the desired path.

From second biobasin **80**, excess water can be decanted for various uses. Alternatively, the water can be conducted to charge pond **90** via conduit **16**. The water in charge pond **90** provides a source of water for flush tank **20** and may be held for an indefinite period until needed. Conduit **16** is configured as described above for conduit **11**.

One method for operating the animal waste treatment system of the present invention will now be described. One embodiment of the present invention includes a barn or alternate animal confinement area. Animals confined within the barn produce animal waste, comprising excrement, spilled food, used bedding and the like. In one embodiment of the present invention, water from flush tank **20** mixes with animal waste from the barn floor, making an animal waste solution. Water from flush tank **20** flushes the animal waste solution into treatment chamber **30** via conduit **11**. Alternatively, animal waste can be manually deposited into treatment chamber **30**, wherein water from flush tank **20** mixes with animal waste to make an animal waste solution.

Treatment chamber **30** is preferably associated with an ozonator, such that ozone is bubbled from the ozonator into chamber **30** to contact the waste solution in an amount sufficient to oxidize at least a portion of any organic material contained in the animal waste solution. The ozone in the ozone-enriched air decomposes organic compounds present in the waste solution. As one of skill in the art will appreciate, the concentration of ozone necessary to treat animal waste is dependent upon a number of variables including: the volume of the treatment chamber; the amount of time animal waste solution is in contact with ozone; the temperature inside the chamber; the presence of ultraviolet light; the presence or absence of agitation; the number of times/day the holding facility is flushed; and the concentration of organic solids in the flushed material.

According to the present invention, the animal waste solution is contacted with ozone for a sufficient length of time to ozonate at least a portion of the organic compounds contained within the solution. The ozone concentration can be at least about 0.01 ppm; preferably from about 0.1 ppm to about 1.0 ppm; and most preferably close to or at saturation.

Following ozone treatment, post-ozonated treated animal waste solution is conducted from waste treatment chamber **30** to settling device **40** via conduit **12**. Settling device **40** comprises a suitable clarifier which permits the flow rate of the post-ozonated waste solution to be slowed, so that heavy solids settle out from the waste solution. For example, settling device **40** may be a concrete pad, such that passage across the pad may slow the flow rate of the post-ozonated waste solution and permit sand and other particulates to be trapped. Following passage across settling device **40**, post-ozonated waste solution is conducted to solids separator **60**

via conduit **13**. According to one embodiment contemplated by the present invention, post-ozonated waste solution enters the top of settling device **40** through conduit **12** positioned at the top of settling device **40**, and exits through conduit **13** positioned at the bottom of settling device **40**, thus allowing gravity to facilitate the filtering of the post-ozone treated animal waste solution.

Conduit **13** conducts the post-ozonated waste solution from settling device **40** to solids separator **60**, wherein suspended particulate matter is further removed from animal waste solution. Post-ozone treated animal waste solution is conducted from solid separator **60** to first biobasin **70**, containing microorganisms configured to biodegrade certain components in the waste solution.

In one embodiment of the present invention, waste solution from first biobasin **70** can be recirculated to treatment chamber **30** via conduit **14**. Conduit **14** further comprises a valve. In a first open position, the valve permits the animal waste solution to be recycled from first biobasin **70** to treatment chamber **30** via conduit **14**, permitting the waste solution to be sequentially contacted with ozone to further reduce contaminants in the waste solution.

In a second closed position, the valve directs the animal waste solution via conduit **14** to second biobasin **80**. Second biobasin **80** may further comprise additional microorganisms, different species or the same as in first biobasin **70**, to degrade the organic components contained in the waste solution.

From second biobasin **80**, the animal waste solution is decanted through discharge line **16** for further use. For example, the excess water decanted from the post-ozonated animal waste solution can be used for irrigation of farmland or, alternatively, used as a source for the irrigation of public property such as golf courses, parks and the like.

Alternatively, the excess water from the treated animal waste solution exiting from first biobasin **70** or from second biobasin **80** can be discharged into charge pond **90** by means of a conduit system containing at least one valve. The water from charge pond **90** can be fed via conduit **17** into tank **20**, thus providing a recirculating source of flush water for the animal waste treatment system.

In one embodiment of the present invention, the ozonated aqueous solution can be fed to a plant system **85** as shown in FIG. **1** for plant growth. For example, some waste materials such as animal waste contain relatively high concentrations of fertilizing nutrients, such as nitrogen, phosphorous and potassium. These nutrients are typically contained in the ozonated solution. In accordance with the present invention, the solution can be fed to the plants that will beneficially remove these nutrients from the solution.

In general, the solution can be fed to any suitable plant or crop. In one embodiment, the solution can be fed to a wetland for use by any vegetation that may be present in the wetland. A wetland is typically defined as a foliage and vegetation area that is configured to accept runoff.

Alternatively, the solution can be fed to plants in a hydroponic system. A hydroponic system involves growing plants in a soil-less system, usually in a liquid medium that provides all essential minerals. For example, a hydroponic system may be a highly regulated and controlled system for growing plant tissue in individual containers. Alternatively, the hydroponic system can be used to grow algae.

In still another embodiment, the solution can be used as irrigation water. For example, the solution can be sprayed over a field or used to irrigate plants grown in greenhouse flats or similar containers.

As shown in FIG. 1, solution discharged from second biobasin **80** can be fed to the plant system. It should be understood, however, that the ozonated solution can be fed to the plant system **85** from other locations. For example, the ozonated solution can be fed to the plant system **85** from the treatment chamber **30**, from the settling device **40**, from the solid separator **60**, and/or from the first biobasin **70**. It should also be understood that the solution can be further contacted with ozone in accordance with the present invention and further ozonated prior to being deposited into the plant system after any of the above locations.

In one particular embodiment of the present invention, waste materials are collected in treatment chamber **30** and ozonated in accordance with the present invention. The ozonated solution is then fed directly into the plant system for plant growth.

Referring now to FIG. 2, an in-line ozonator useful in the present invention is illustrated. In general, the in-line ozonator can be used to replace treatment chamber **30** in the present invention when small volumes of low particle waste water are to be treated. Also contemplated by the present invention is placing an in-line ozonator anywhere in the system illustrated in FIG. 1 between any of the components. However, it should be appreciated that many other various uses for an in-line ozonator exist. For example, in accordance with the present invention, an in-line ozonator can be placed in a golf course and used to treat irrigation water.

It should be understood that the in-line ozonator can be used to treat any malodorous waste water or low particulate waste water in accordance with the present invention.

In-line ozonator system **24** broadly comprises ozonator **21**, connected to u-shaped tube **23** by at least one connector **22**; u-shaped tube **23**, connected via a first swivel joint **25** to inlet **27** and connected via a second swivel joint **25** to outlet **28**; tank **20** and cover **26**. As shown, u-shaped tube **23** includes a bottom section **29** which is at an elevation lower than inlet **27** and outlet **28**. Inlet **27** and outlet **28**, in this embodiment, are axially opposed.

Ozonator **21** preferably comprises an ozone generator to generate ozone from air and/or oxygen and produce ozone-enriched air. Ozonator **21** further includes a source of electricity to produce ozone. Preferably the electricity source comprises a photovoltaic array, however, one of ordinary skill in the art will recognize that other mechanisms for generating electricity may be suitable for use in the present invention. Ozonator **21** is connected to u-shaped tube **23** by at least one connector **22**.

As embodied by the present invention, connector **22** may comprise a tube, pipe, channel or other device suitable to allow ozone to enter u-shaped tube **23**, permitting ozone to contact the waste solution in an amount sufficient to oxidize at least a portion of any organic material contained in the animal waste solution. In a preferred embodiment, ozonator **21** permanently connects u-shaped tube **23** by connector **22**, however, a non-permanent connection between ozonator **21** and u-tube **23** via connector **22** is contemplated by the present invention.

U-shaped tube **23** preferably comprises first and second swivel joint **25**. First swivel joint **25** connects u-shaped tube **23** to inlet **27**, permitting entry of the animal waste solution into u-shaped tube **23** to contact ozone. Second swivel joint **25** connects u-shaped tube **23** to outlet **28**, permitting the egress of post-ozonated waste solution.

During waste treatment operation, u-shaped tube **23** is positioned in a first position as shown in FIG. 2, having bottom **29** at the lowest point of u-shaped tube **23**. To

facilitate flushing and removing of sediment, u-shaped tube **23** can be swivelled into a second position, via first and second swivel joint **25**, such that bottom **29** is positioned at highest point of u-shaped tube **23**.

The use of the u-shaped tube **23** offers various benefits and advantages. In particular, the use of a u-shaped tube ensures that the nozzle of the ozonator remains completely immersed in the solution flowing through the tube, even under low flow conditions. For example, in low flow conditions, the fluid being treated will accumulate in the u-shaped tube even though the inlet **27** and the outlet **28** may only be partially be filled with fluid.

As contemplated by the present invention, tank **20** comprises a tank, drum, chamber, or other container suitable for holding u-shaped tube **23** and ozonator **21** and having a sufficient diameter to permit u-shaped tube **23** to swivel for operation. Tank **20** further comprises cover **26** permitting access to ozonator system **24**.

Referring to FIG. 6, an alternative embodiment of an in-line ozonator generally **100** is shown. In this embodiment, in order to contact a solution containing organic compounds with ozone, the system includes an inlet **127** separated from an outlet **128** by a venturi **110**. Venturi **110** is in communication with ozonator **121**. A venturi is a constriction that is placed in a pipe or tube that causes a drop in pressure as fluid flows through it. As shown in the figure, the venturi can include a straight section or a throat positioned in between two tapered sections. When used in the process of the present invention, the venturi draws the ozone into the main flow stream.

Using a venturi in the system of the present invention offers various advantages. For instance, the venturi allows the ozone to rapidly combine with the solution containing the organic compounds to be treated. Thus, a maximum amount of ozone can be dissolved into the solution. Further, better mixing between the ozone and the organic compounds is achieved using the venturi.

Venturi **110** can be used in the system illustrated in FIG. 1 in order to feed ozonated water to the treatment chamber **30** (see inlet **127** and outlet **128** in phantom to illustrate U-shaped embodiment). For example, in one embodiment, the venturi **110** can be placed within a circulation conduit that is placed in communication with treatment chamber **30**. The solution accumulated in the treatment chamber **30** can then be pumped using a pump through the circulation conduit and into the venturi for contact with ozone. The solution contained within the treatment chamber can be repeatedly circulated through the circulation conduit until the solution is ozonated to the extent desired.

Alternatively, the in-line ozonator can also be used for treating any aqueous solution.

The present invention may be better understood with reference to the following examples.

EXAMPLE 1

Ozone Treatment of Animal Waste

For each experimental replication, samples of wastewater (about 1 pint each) were collected from the LaMaster Dairy Farm barn flush system (Clemson University, Clemson, S.C.). To ensure a representative sample of barn flushwater was treated, samples were collected from the beginning, middle, and end of a barn flush cycle such that the total volume collected was approximately 1.0 gallon. Samples collected from each timepoint were commingled and immediately transported to the laboratory.

In the lab, samples were thoroughly mixed before treating individual samples (final volume of each sample ranged from about 50 mls to about 2.0 L) according to the present invention.

Ozone, generated by a PUREPOWER ozonator (Longmark Ozone Industries, Yreka, Calif.), was bubbled through the wastewater samples for 20 minutes at a concentration of from about 0.3 ppm ozone to about 0.4 ppm ozone. Samples of the wastewater, collected in test tubes before and after ozone treatment, were analyzed for biochemical oxygen demand (BOD), chemical oxygen demand (COD), total bacteria count, coliform bacteria count, and for malodorous aromatic compounds by reverse phase chromatography.

EXAMPLE 2

BOD Levels in Post-treated Wastewater

Biochemical Oxygen demand (BOD) was measured by the 5-day BOD test method. Experimental protocols for measuring BOD can be readily obtained from consulting standard reference texts such as Section 5210 B of Standard Methods for the Examination of Water and Wastewater, 19th edition, 1995; Eaton, A.D., L.S. Clesceri, and A.E. Greenberg, eds. (American Public Health Association, Washington, D.C.; the contents of which is incorporated in its entirety) without undue experimentation.

FIG. 3A is a graphic illustration comparing the BOD in the wastewater effluent before ozone-treatment to that following treatment according to the present invention. FIG. 3A shows a significant reduction in BOD occurs as a result of treatment, from approximately 5000 mg/L to approximately 1000 mg/L.

EXAMPLE 3

Total Bacteria Count in Post-treated Wastewater

Total aerobic bacteria counts may be determined by using standard experimental methods, such as the aerobic plate count method outlined in chapter 3 of the FDA Bacteriological Analytical Manual, 8th edition, 1995 (AOAC International, Gaithersburg, MD; the contents of which is incorporated in its entirety) without undue experimentation.

FIG. 3B is a graphic illustration comparing the total aerobic bacteria count in the wastewater effluent before ozone-treatment to that following treatment according to the present invention. FIG. 3B shows a significant reduction in total aerobic bacteria count occurs as a result of treatment, from approximately 8 log CFU/ml to approximately 5 log CFU/ml.

EXAMPLE 4:

Coliform Bacteria Count in Post-treated Wastewater

Coliform bacteria were enumerated in the before and after samples by using the violet red bile agar (VRBA) solid media method as outlined in chapter 4, section E, of the FDA Bacteriological Analytical Manual, 8th edition, 1995 (AOAC International, Gaithersburg, MD; the contents of which is incorporated in its entirety).

FIG. 3C graphically illustrates the number of coliform bacteria present in wastewater before treatment as compared to the coliform bacteria present in samples treated according to the present invention. As can be seen from the graph in FIG. 3C, a significant reduction in coliform counts of about

4 logs occurs following treatment, from approximately 7 log CFU/ml to approximately 3 log CFU/ml.

EXAMPLE 5

COD levels in Post-treated Wastewater

Chemical oxygen demand (COD) was measured by the Closed Reflux, Colimetric Method. Experimental protocols for measuring COD can be readily obtained from consulting standard reference texts such as Section 5220 D of Standard Methods for the Examination of Water and Wastewater, 19th edition, 1995; Eaton, A.D., L.S. Clesceri, and A.E. Greenberg, eds. (American Public Health Association, Washington, D.C.; the contents of which is incorporated in its entirety) without undue experimentation.

FIG. 3D is a graphic illustration comparing the COD in the wastewater effluent before ozone-treatment to that following treatment according to the present invention. FIG. 3D shows a significant reduction in COD occurs as a result of treatment, from approximately 9000 mg/L to approximately 4000 mg/L.

EXAMPLE 6

Levels of Malodorous Aromatic Compounds in Post-treated Wastewater

Malodorous aromatic compounds (indole, skatole, cresol, and the like) were analyzed by high pressure liquid chromatography (HPLC) using a water/acetonitrile gradient and a C5 reverse phase column (Phenomenex, Torrance, Calif.). Detection was at 280 nm using the Rainin gradient DYNAMAX system with Macintosh computer control and METHOD MANAGER SOFTWARE (Rainin Instrument Co., Woburn, Mass.).

FIG. 4 is a graph illustrating the results of reverse phase high powered liquid chromatography (HPLC) analysis of the components responsible for the odor associated with animal waste. As can be seen in the HPLC graph, following treatment according to the present invention, levels of the odoriferous components are significantly reduced.

FIG. 5 is a photograph showing the appearance of wastewater effluent before treatment (5A) as compared to the appearance of effluent treated according to the present invention (5B). FIG. 5 shows that the treated waste solution is clear and colorless as compared to the pre-treated effluent.

Although preferred embodiments of the invention have been described using specific terms, devices, concentrations, and methods, such description is for illustrative purposes only. The words used are words of description rather than of limitation. It is to be understood that changes and variations may be made without departing from the spirit or the scope of the following claims.

What is claimed is:

1. A system for treating an aqueous solution comprising:
 - a u-shaped tube;
 - an inlet tube connected to said u-shaped tube, said inlet tube being connected to said u-shaped tube via an inlet swivel joint;
 - an outlet tube connected to said u-shaped tube, said outlet tube being connected to said u-shaped tube via an outlet swivel joint; and
 - an ozonator, said ozonator being in communication with said u-shaped tube, said ozonator being configured to deliver ozone to said u-shaped tube for combining an aqueous solution flowing through said tube with ozone,

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said ozone being delivered to said u-shaped tube by said ozonator in amounts sufficient to oxidize organic matter contained in said aqueous solution.

2. A system as defined in claim 1, wherein said inlet tube and said outlet tube are axially opposed.

3. A system as defined in claim 1, wherein said u-shaped tube is connected to said inlet tube and to said outlet tube in a manner that permits axial rotation.

4. A system as defined in claim 1, wherein said ozonator further comprises a nozzle positioned within said u-shaped tube through which ozone is emitted.

5. A system as defined in claim 4, wherein said u-shaped tube includes a bottom section, said nozzle of said ozonator being located in said bottom section.

6. A system as defined in claim 5, wherein said bottom section of said u-shaped tube is at an elevation lower than said inlet tube and said outlet tube.

7. A system as defined in claim 1, further comprising a pump configured to pump said aqueous solution into said inlet tube.

8. A system as defined in claim 1, wherein said ozonator comprises an ozone generator configured to generate ozone from air.

9. A system as defined in claim 1, further comprising a containment chamber surrounding said u-shaped tube.

10. A system for treating an aqueous solution with ozone comprising:

- a venturi including a first end and second end;
- an inlet tube in fluid communication with said first end of said venturi, said inlet tube for receiving an aqueous solution to be treated;
- an outlet tube in fluid communication with said second end of said venturi;
- a u-shaped tube connected to said inlet tube at one end and to said outlet tube at an opposite end and having a bottom section, said venturi being located along said bottom section; and
- an ozonator, said ozonator being in communication with said venturi, said ozonator being configured to feed ozone into said venturi for combining with said aqueous solution in amounts sufficient to oxidize matter contained in said solution.

11. A system as defined in claim 10, further comprising a pump configured to pump said aqueous solution into said inlet tube.

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12. A system as defined in claim 11, wherein said inlet tube and said outlet tube are placed in fluid communication with a treatment chamber and wherein a solution contained in said treatment chamber is directed through said venturi for ozonating said solution.

13. A system as defined in claim 10, wherein said bottom section of said u-shaped tube is at an elevation lower than said inlet tube and said outlet tube.

14. A system as defined in claim 10, wherein said inlet tube and said outlet tube are placed in fluid communication with a treatment chamber and wherein a solution contained in said treatment chamber is directed through said venturi for ozonating said solution.

15. A device for treating an aqueous solution with ozone comprising:

- a u-shaped tube including a first end and a second end;
- an inlet tube connected to said first end of said u-shaped tube, said inlet tube being connected to said u-shaped tube in a manner that allows said u-shaped tube to swivel;
- an outlet tube connected to said second end of said u-shaped tube, said outlet tube being connected to said u-shaped tube in a manner that allows said u-shaped tube to swivel; and
- an ozonator, said ozonator being in communication with said u-shaped tube, said ozonator being configured to form ozone and to deliver said ozone to said u-shaped tube for combining with an aqueous solution flowing through said tube, said ozone being fed to said u-shaped tube in an amount sufficient to oxidize organic matter contained within said aqueous solution.

16. A system as defined in claim 15, further comprising a venturi located along said u-shaped tube, said ozonator being in fluid communication with said venturi for feeding said ozone to said venturi.

17. A system as defined in claim 15, wherein said ozonator further comprises a nozzle positioned within said u-shaped tube through which ozone is emitted.

18. A system as defined in claim 15, wherein said u-shaped tube includes a bottom section, said nozzle of said ozonator being located in said bottom section.

19. A system as defined in claim 18, wherein said bottom section of said u-shaped tube is at an elevation lower than said inlet tube and said outlet tube.

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