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(54) Title: PORTABLE/MOBILE WASTEWATER TREATMENT UNIT

(57) Abstract: The invention is directed to a portable/mobile biological treatment and water-recirculating apparatus for delivering activated microorganisms to an environment to be treated. The unit has at least one biological wastewater treatment unit, aeration unit, biological nitrification unit, and re-circulating pump for circulating the wastewater to be treated and a controller to maintain the conditions of the bioreactor so as to maintain the microorganisms in the exponential phase of growth. The invention also provides a method for the biological treatment of wastes and an organic and inorganic nutrient composition used to feed the microorganisms in the bioreactor.



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PORTABLE/MOBILE WASTEWATER TREATMENT UNIT

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CROSS REFERENCE

This application claims priority under 35 U.S.C. § 119(e)(1) of provisional application number 60/397,404 filed July 19, 2002.

FIELD OF THE INVENTION

A portable/mobile biological treatment and water recycling apparatus comprising a shed, cabinet, truck, pickup, trailer or other wheeled container having at least one biological wastewater treatment unit, aeration unit, biological nitrification unit, and circulating pump for circulating the wastewater to be treated. The biological wastewater treatment unit introduces pre-conditioned living organisms to the environment to be treated in order to biodegrade the waste. The nitrification unit introduces pre-conditioned living nitrifying organisms for the biological breakdown of nitrogen-based wastes, such as ammonia, nitrates, nitrites and other contaminants contained in waste water streams, ground water, soil, lagoons, etc. The circulating pump circulates the wastewater in the environment to be treated aerating the wastewater and floating digestible solids. The aeration unit pumps dissolved oxygen into the wastewater environment so that aerobic respiration can take place.

BACKGROUND OF THE INVENTION

Over the past decades there has been a shift from smaller localized family farms toward larger integrated confinement agricultural operations. Specifically, large agricultural operations may utilize confinement barns to house a large number of livestock such as swine, poultry or dairy cows. Using the swine industry as an example, often numerous hog-confinement operations are grouped in close proximity forming "mega-farms" which may house tens of thousands of hogs. While these

larger agricultural operations have numerous advantages; attendant with these larger facilities are pollution problems relating to the handling and treatment of manure and wastewater (hereinafter collectively "wastewater"). By way of example, pollution problems associated with liquid animal waste, such as produced by the swine industry, include nitrogen, phosphorus, solids, bacteria and foul odors that result from anaerobic digestion. Environmental concerns more specifically center on odor and water quality issues.

Currently, most agricultural facilities use anaerobic digestion for treatment of animal wastes and wastewater. The primary reasons for using anaerobic digestion is simplicity and cost. Wastewater is simply discharged from the animal storage facility into an open lagoon or plurality of lagoons (ponds used to store and treat thousands to millions of gallons of animal waste) where the waste undergoes natural anaerobic digestion. However, over forty (40) noxious gases may be emitted from anaerobic lagoons at hog farms including ammonia, methane and hydrogen sulfide. Additionally, the time required for complete digestion of the organic wastes is relatively long, from weeks to months. Some current regulations require a residence time of 180 days for animal waste facilities using anaerobic lagoons for digestion.

Neighbors find odors emanating from lagoons, confinement houses, and fields onto which wastes are sprayed to be a nuisance. In fact, as a result of odor problems associated with anaerobic lagoons, certain states have legally mandated buffer zones or designated land areas between lagoon sites and populated areas.

New studies have shown that lagoons are leaking and there have been pollution problems with the groundwater, rivers, lakes and coastal waters primarily in states where the high concentrations of hog farms are located. Another problem attendant with traditional anaerobic settling lagoons is that occasionally the water overflows the lagoons or the

earthen containment berms collapse, primarily during periods of heavy rainfall, and the wastewater runs-off into streams, rivers and lakes causing severe pollution problems. When wastewater escapes from these lagoons either resulting from overflows or other failures, the high concentrations of pollutants has adverse effects on the receiving waters and commonly results in groundwater contamination and massive fish and other aquatic life kills. A major contributor to the high concentration of pollutants in the lagoons are the nitrogen-based compounds.

The present invention relates to a portable/mobile biological treatment and water-recycling apparatus comprising a shed, cabinet, truck, pickup, trailer or other wheeled container having at least one biological wastewater treatment unit, aeration unit (preferably an air injection unit), biological nitrification unit, and circulating pump for circulating the wastewater to be treated. More specifically, the present invention relates to a portable/mobile biological wastewater treatment unit that incubates and dispenses large amounts of nitrifying microorganisms and organic digesting microorganisms in log-growth phase.

The nitrifying microorganisms biologically digest the nitrogenous waste during a process called nitrification that takes place in the aerobic environment. This sets the stage for the final removal of nitrogen from the environment to be treated via an anaerobic de-nitrification process.

During nitrification, the ammonia content in the environment to be treated is converted to nitrate, utilizing the organic carbon content of the wastewater. During de-nitrification, the nitrate is converted to gaseous nitrogen, also requiring the use of organic carbon. In many instances, the environment to be treated after nitrification does not contain sufficient organic carbon for effective de-nitrification. Accordingly it is frequently

necessary to add supplemental organic carbon to the de-nitrification zone, commonly in the form of methanol.

The organic digesting microorganisms aerobically metabolize organic carbon waste in the environment to be treated into carbon dioxide, water and inorganic side products. Even though the biologically mediated processes of nitrification and de-nitrification, and conversion of ammonia to free nitrogen are well known, improvements in conventional methods of treating wastewater containing high levels of ammonia, organic material and other contaminants are still needed. The research and development to upgrade the performance of biological treatment systems to handle high ammonia containing organic liquids as well as organic material has been basically considered unsuccessful to date.

One problem with a current method, the activated sludge system, is the operation of handling large amounts of sludge. This system treats the sludge by circulating the nitrogen containing waste into a tank, treating the tank with nitrifying microorganisms and then circulating the treated wastes back into the environment being treated. This system does not simultaneously treat the waste with organic waste digesting microorganisms. Therefore the organic material is unaffected. In practicality, circulating sludge from a food processing plants and/or lagoons used to collect animal waste in an animal harvesting operating is extremely energy inefficient and costly. And treating the waste for high concentrations of nitrogen-based compounds does not completely solve the problem of waste build-up. For example, an animal waste containing 5 acre lagoon holds over 10 million gallons of waste and it would take an enormous amount of energy to direct the waste into holding tanks so that they can be treated with nitrifying microorganisms and released. This process is simply cost prohibited.

Another problem with such systems is that activated sludge is known to be highly sensitive to variations in pH level, temperature, nutrient concentration changes, and toxicity

shifts and other biological growth-influencing shifts. Still another problem with such systems is that the natural biological digestion of organic waste, if left non-augmented, takes very long periods of time. Often the natural biological digestion process is slow and unable to keep up with the amount of organic waste added on a daily bases. Thus causing large accumulations of organic waste that, if left to nature, would take years maybe tens of years to fully digest.

As stated above, wastes, under normal conditions, are gradually broken down or biodegraded by indigenous microorganisms in the environment. In addition to being slow, biodegradation reactions are often hindered by environmental fluctuations such as changes in temperature, pH, salinity, water and air supply, etc. For example, wastes such as fat and grease are biodegraded by microorganisms to fatty acids and glycerol. In the presence of oxygen the fatty acids are further metabolized with the end product being carbon dioxide and inert by-products. Glycerol is also metabolized as an efficient energy source.

As for the natural nitrification of nitrogenous waste, nitrifying microorganisms are not normally present in high enough levels to effectively breakdown nitrogenous waste. In addition, since the majority of waste lagoons are anaerobic and nitrifying microorganisms only exist in aerobic environments, the majority of waste lagoons do not naturally contain nitrifying microorganisms. A portable/mobile all-in-one on-site apparatus that produces large amounts of activated nitrifying microorganisms in log growth phase as well as large amounts of activated organic microorganisms in log growth phase overcomes the shortcomings of existing systems.

SUMMARY OF THE INVENTION

The present invention provides a portable/mobile wastewater bio-augmentation system that adjusts the environment to be treated to a condition that is more conducive for

bio-degradation of waste by introducing activated microorganisms designed to digest organic waste as well as nitrogen-based waste. Activated microorganisms are microorganisms that are in the exponential phase of growth. These microorganisms are more efficient in the biodegradation of waste than microorganisms that are not in the exponential phase of growth.

The present invention provides methods and apparatuses for the continuous cultivation of evolving bacterial consortia and by-products for direct utilization in bioremedial and bioaugmentation applications, such that the digestion and mobilization of organic waste and nitrogen-based waste in plants, lagoons, and treatment systems or natural contaminated sites are treated.

In general, the portable/mobile biological treatment and water recycling apparatuses include a portable/mobile transport device such as a shed, cabinet, truck, pickup, trailer or other wheeled container, a bioreactor nitrifier for activating and growing microorganisms that digest organic waste, a nutrient reservoir source for feeding the microorganisms in the bioreactor, a bioreactor nitrifier for activating and growing nitrifying microorganisms and facultative anaerobic de-nitrifying microorganisms, a nutrient reservoir source for feeding the nitrifying microorganisms in the bioreactor, an aeration unit (preferably an air injection unit), a circulating pump for circulating the wastewater to be treated and a controller for managing and monitoring the continuous delivery of the biology from bioreactors as well as the operation of the circulating pumps. The portable/mobile transport vehicle is equipped with all the circuitry and/or power supply necessary to operate the pumps, heaters, aeration system and controller. In an alternative embodiment the aeration unit is an air injection unit fitted at the outflow of the re-circulating pump.

In one embodiment of the present invention, a portable/mobile apparatus for delivering microorganisms to an environment to be treated comprising a structure having an interior space, a bioreactor vessel having a bioreactor output port positioned within the structure, a nutrient container comprising a mixture of inorganic and organic nutrients positioned within the structure, a nutrient pumping means for pumping inorganic and organic nutrients from the nutrient container to the bioreactor, a water pumping means for pumping water into the bioreactor, the water pumping means is in fluid communication with the bioreactor and a water source wherein the water pumped into the bioreactor displaces fluid out of the bioreactor output port, a recirculation pump positioned within the structure in fluid communication with the environment to be treated, and a controller in communication with the recirculation pump, the nutrient pumping means, and the water-pumping means, the controller activating and deactivating the recirculation pump, the nutrient pumping means, and the water pumping means according to a predetermined schedule.

In another embodiment of the present invention, the portable/mobile wastewater bio-augmentation system is equipped with a continuous monitoring system that monitors functioning of the components of the system and electronically notifies, via e-mail, pager alerts and/or cell phone calls, whether a component of the system has malfunctioned or failed. The monitoring system can also be used to send data from sensors positioned either in the bioreactor, nitrifier or in the environment being treated to a home base. This information can be used to access the condition/state of the bioreactor or nitrifier, access the condition of the environment to be treated and/or simply to collect real time data from the environment to be treated.

In another embodiment of the invention, the portable/mobile wastewater bio-augmentation system is connected to a distribution/delivery system that delivers the

growing microorganisms that digest organic waste and/or nitrifying microorganisms and/or facultative anaerobic de-nitrifying heterotrophs to the environment to be treated in an effective, comprehensive way. The delivery system comprises a pump-manifold system that is situated around, within and/or above the site being treated so as to deliver the microorganisms and oxygen most effectively.

The manifold system may consist of polyvinylchloride (PVC) piping, flexible hose (or equivalent material), oxygen generating restriction nozzles (eductor nozzles), gate valves and spray nozzles. The design of the manifold is important for the stability and reproductive capabilities of the microorganisms, as well as the oxygen transfer. It is important that the manifold be designed so that the oxygen and microorganisms are delivered above and below the surface of the treatment site to assure proper flow rates so as to achieve hydraulic shearing and oxygen saturation of the recycled waste water.

DETAILED DESCRIPTION OF THE INVENTION

An apparatus according to the present invention comprises six main subsystems: a portable/mobile container; a controller unit; a bio-augmentation system for growing organic digesting microorganisms; a bio-augmentation system for growing nitrifying microorganisms; potable water reservoir and regulator; and a recirculation pump. Each subsystem constitutes a separate part of the invention.

The portable/mobile container used to house and transport the wastewater bio-augmentation system of the present invention may be selected from the group consisting essentially of shed, cabinet, trailer, pickup truck, boat, barge, truck, or a wheeled container. The portable/mobile container chosen will depend on the environment and conditions of the environment where the unit will be deployed. Regardless of the portable/mobile container chosen, the container will be modified so as to house the components of the wastewater

treatment system described below. In view of the fact that microorganisms are sensitive to weather changes, the portable/mobile container may be equipped with a heating system and/or a cooling system controlled by a thermostat and or the controller. The heating/cooling system will maintain the internal temperature of the portable/mobile unit within a pre-determined range.

The portable/mobile container shall be equipped with a controller unit that houses and protects electronic components and isolates electrical components, along with fuses and electrical boards, and connections for safe operation of the system and to comply with applicable standards. The controller is in communication with the other main subsystems of the portable/mobile wastewater treatment system. More specifically, the controller will regulate the function of the pumping systems of water, nutrients, and dosing in the bio-augmentation system for growing organic digesting microorganisms as well as the bio-augmentation system for growing nitrifying and de-nitrifying microorganisms. The controller also controls the recirculation pump of the system. The types and numbers of pumps are not critical. For instance, a pump may be positioned to operate each input into the organic digesting bioreactor and/or the nitrifier, e.g. from water reservoir, nutrient container and atmosphere (to provide air to the bioreactor, for instance, to enable aeration). The pumps may be single or multi-chambered pumps or other appropriate pumping mechanism known in the art.

The bio-augmentation system for growing organic digesting microorganisms comprises at least one bioreactor that provides an environment conducive for the culturation of microbes, and includes at least one container. The bioreactor may include one or more of the following: a heater (such as a thermostatically controlled heater), a temperature control, an aeration means, organic and inorganic nutrients, check valves for isolation of the bioreactor, and pipes and/or tubing to provide for aeration, water, dosing of the

microorganisms to a dosing tank and for delivery of the nutrient formulation to the bioreactor.

The dosing cycles for potable water and nutrient delivery to bioreactor (from the nutrient nitrifier) are set to the same number of cycles per day, generally 4, 8 to 16, preferably 6 to 12. These cycles are controlled by the turning on and off of the nutrient and water pumps connected to the bioreactor and are controlled by the controller or a timer. The controller can be programmed to turn the nutrient pumps on and off at different times of the day. Therefore, in a 2-timer embodiment, nutrient delivery to the bioreactor should lag water delivery by 15 to 60 minutes, depending on the spacing of cycles. When used with a formulation the ratio of amount of potable water (by volume) to nutrient should be between 50 to 200, preferably 75 to 125. The requisite ratio may be achieved by calibrating the respective transfer pumps accordingly. The total daily volume of effluent produced is approximately equal to the total daily volume of potable water and nutrients delivered to the bioreactor. In operation, the potable water delivered to the bioreactor should be set from about 1 to about 12 times the total volume of bioreactor, preferably from about 2 to about 6 times the volume. The temperature of the bioreactor is set on a heater and should be from about 60 degrees F to about 120 degrees F, preferably from about 80 degrees F to about 100 degrees F.

Dosing of activated microorganisms from the bioreactor into the dosing tank of the portable/mobile system occurs continuously and steps up about 4 to about 16 times a day, preferably about 6 to about 12 times a day, most preferably about 4 to about 8 times a day. The continuous bioreactor system doses continuously and is stepped up when the composition is displaced from the bioreactor upon addition of water into the bioreactor. Once dosed into the dosing tank the activated log-phased microorganisms enter the environment to be treated and begin to digest organic material immediately.

The process may be initiated by starting water and nutrient flow to the bioreactor used to produce activated log-phase microorganisms that digest non-nitrogen containing organic contaminants. For instance, by cycling the nutrient and water pumps enough times to fill the organic digesting microorganism bioreactor. This, along with the heat and aeration, will start the germination process. After initiation, there will be copious bubbling of the composition in the bioreactor, now inoculated with microorganisms capable of digesting non-nitrogen containing material. The resulting aeration aids the overall growth and colonization of the bacterial species. In time, the bacterial substrate utilization rates of the nutrients approach that of delivery rates. The organization of the bacteria consortium will in general continually tend to improve overall over time as the species co-adapt to maximize target type substrate utilization.

In preparing the bioreactor for growing microorganisms that digest non-nitrogen containing waste, the bioreactor compartment is sterilized by cleaning it with, or otherwise applying, a suitable disinfectant agent to the surface. For instance, a 70% ethanol solution, or some similar alcohol based surface active disinfectant may be used. After the bioreactor has been suitably sterilized, a suspended bacterial product that is designed to produce microorganisms that digest non-nitrogen organics waste, either in desiccated or in liquid spore-like form, is added to the bioreactor compartment. Preferably, the bacterial product is enclosed in a 1/16 inch steel mesh ball, and contains from about 1 to about 15 grams of bacterial composition. The bioreactor is then sealed and all connections are capped off until after installation.

The microorganisms employed in the starter material may vary, but all of which digest non-nitrogen containing organic waste material. In one embodiment, where the microorganisms are used to degrade hydrocarbons, i.e. grease, the starter material contains at least one microorganism selected from the group consisting essentially of Bacillus

licheniformis, Bacillus subtilis, Pseudomonas fluorescens E, Pseudomonas putida, Enterobacter cloacae, and Bacillus thuringienis. A preferred bacterial product that may be employed is Bi-Chem® SM 700 from Sybron, Inc., of Salem, Va. which is a blend containing 8 non-pathogenic organisms capable of digesting organic grease and fats. The starter material generally has a concentration of cells of at least $\sim 1 \times 10^8$ per fluid ml as well as the essential inorganic and organic nutrients to maintain the cell culture in the exponential phase of growth. The content and concentration of the inorganic and organic nutrients in the food will vary with the type of microorganism used in the apparatus.

In order to get the microorganisms that digest organic material into an activated log-phase growth, prior to dosing specialized media is used. A composition containing organic and inorganic nutrients may be in either a liquid or solid (e.g. powdered) matter state. If a liquid, the formula may have a pre-determined concentration, the preferred concentration is on the order of 100 times. An embodiment of a composition containing organic and inorganic nutrients that is used as part of a starter material generally includes a metal-oleate, preferably K-oleate, and one or more of magnesium sulfate, calcium chloride, potassium phosphate, sodium phosphate, sodium EDTA, sodium hydroxide, ferric NH citrate, potassium bicarbonate, sodium chloride, dextrose, citrate, yeast extract, whey extract, ketrol, ammonium nitrate, ammonium chloride, glycerin, Tween 20, Tween 80, corn oil, Simethicone, and trace elements that include but are not limited to copper sulfate, cobalt(II) chloride, Sodium EDTA, Molybdic acid, $\text{MnCl}_2 \cdot 7\text{H}_2\text{O}$, and zinc sulfate.

Preferably the composition containing organic and inorganic nutrients includes about 50 to about 60 weight % of water, about 20 to about 30 weight % K-oleate, about 2 to about 3 weight % glycerin, about 3 to about 10 weight % of vegetable oil and less than about 1 weight % of compounds selected from the group consisting essentially of MgSO_4 , CaCl_2 , $\text{NaHPO}_4 - 7\text{H}_2\text{O}$, K_2HPO_4 , NaCl , Dextrose, Citrate, Yeast Extract, Whey Extract,

Trace elements, Sodium EDTA, Keltrol, Ferric NEcitrate, NaOH, NH_4NO_3 , NH_4Cl , Tween 20, Tween 80, and Simetblycone. Most preferably the vegetable oil is a mixture of about 4 to about 5 weight % of corn oil and about 5 to about weight 6% canola oil peanut oil.

The composition containing organic and inorganic nutrients can be prepared by mixing metal-oleate, glycerin, Tween 20, Tween 80, water, and Keltrol in a mixing kettle. MgSO_4 , CaCl_2 , Sodium EDTA is added to 1 gallon of water and the pH is brought to about 8 to about 10, preferably about 9 using about 10N NaOH. This mixture is then added to the mixing kettle and is mixed for about 2 minutes. To about 5 gallons of water the $\text{Na}_2\text{HPO}_4 \cdot \text{H}_2\text{O}$ and K_2HPO_4 is added. The pH is brought to about 8 to about 10, preferably about 9 using about 10N NaOH. This mixture is added to the mixing kettle after 2 minutes of mixing.

The NaCl , Dextrose, Citrate, Yeast Extract, Whey Extract, NH_4NO_3 , NH_4Cl , $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$, CuSO_4 , Na_2EDTA , Molybolic Acid, $\text{MnCl}_2 \cdot 4\text{H}_2\text{O}$, $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$, Vitamin A, Vitamin D, Vitamin E, Vitamin K, Thiamin, Riboflavin, Niacin, Vitamin B6, Folic Acid, Vitamin B₁₂, Biotin, Pantothenic Acid, Calcium, Iron, Phosphorous, Iodine, Magnesium, Zinc, Selenium, Copper, Mn, Chromium, Molybdenum, Chloride, Potassium, Boron, Nickel, Silicon, Tin, and Vanadium are mixed in about 8 gallons of water.

In a separate container Sodium EDTA and ferric NHcitrate is dissolved in about 200ml of hot water and then added to the composition. The 8-gallon mixture brings the pH of the total composition to a pH of from about 9 to about 10, preferably about 9. The mixture is then added to the mixing kettle. Finally, corn oil and canola oil are added to the mixing kettle, and NH_4NO_3 and NH_4Cl are sprinkled into the mixing kettle. The combined mixture is mixed thoroughly and filled into a dispensing container immediately. An anti-foaming agent may then be added. The pH of the final mixture should be from about 9 to about 10, preferably from about 9.3 to about 9.6.

As explained above, when the composition is used as a starter material, at least one microorganism is added. The microorganism may be selected from the group of microorganisms (and may consisting essentially of (or consist of) Bacillus licheniformis, Bacillus subtilis, Pseudomonas fluorescens E, Pseudomonas putida, Enterobacter cloacae, and Bacillus thuringiensis, and may be added prior to inoculation of the bioreactor. It is within the scope of the invention to substitute microorganism not listed that are capable of digesting waste.

The portable/mobile wastewater treatment unit may also include a nitrification and de-nitrification system. The nitrification/de-nitrification system comprises a bioreactor that provides an environment conducive for the cultivation of nitrifying microorganisms as well as assorted facultative anaerobic heterotrophs. The heterotrophs are capable of de-nitrification and stabilize and buffer the system. In particular, the facultative anaerobic heterotrophs help with de-nitrification when the oxygen concentration is reduce or shut-off and therefore aide in keeping the pH of the system within a predetermined range. In addition, the hetertrophs help with the production of bio-films that are important in properly seeding the environment being treated.

The bioreactor may include one or more of the following: a heater (such as a thermostatically controlled heater), a temperature control, an aeration means, organic and inorganic nutrients, a recirculation pump attached to inductor mixing nozzles, a pH buffer port, a pH buffer pump, a booster inoculation port, a booster inoculation pump, a pH probe, an inspection sampling port, an inoculation port, an inoculation pump, potable water input, an attached growth substrate for increased surface area, check valves for isolation of the bioreactor, and pipes and/or tubing to provide for aeration, nutrients, booster inoculations and dosing.

The dosing cycles for potable water and nutrient delivery to bioreactor (from the nutrient nitrifier) are either set to the same number of cycles per day, generally 4, 8 to 6, preferably 6 to 12. In the embodiment where the nitrifying consortium is dispensed each time the bioreactor reaches a pre-determined pH, the same number of cycles may not occur each day.

In a two nutrient container delivery system, the first container comprising Media A that generally includes $(\text{NH}_4)_2\text{SO}_4$; K_2HPO_4 ; Fe ; MgSO_4 ; CaCl_2 ; EDTA; and trace elements that include but are not limited to CuSO_4 , Co(II)Cl , Molybolic acid, $\text{MnCl}_{12} \cdot 7\text{H}_2\text{O}$, and ZnSO_4 is dosed to the bioreactor every 2-4 hours. The second container comprising Media B that generally includes KHCO_3 ; a sugar source (*e.g.* dextrose); and an amino acid source (*e.g.* peptone) is also dosed every 2-4 hours and is slightly off-phase with the cycle of the first container.

In another embodiment containing two nutrient containers both Media A and Media B are in the same container and are dosed every 2-4 hours. The size of the bioreactor can range from several liters to several hundred gallons. Assuming the bioreactor is 25 gallons then 50 ml of Media A and 50 ml of Media B is added to the bioreactor every 2-4 hours. As the bioreactor increases in size the amount of Media A, and Media B increases proportionally to the increased size of the bioreactor nitrifier.

When used with a formulation the ratio of amount of potable water (by volume) to Media A, Media B the Media should be between about 25 to about 50, preferably 40. The ratio of amount of potable water (by volume) to Media C should be between 75-150, preferably 140. The requisite ratio may be achieved by calibrating the respective transfer pumps accordingly. The total daily volume of effluent produced is equal to the total daily volume of potable water delivered to the bioreactor.

Booster inoculations may be used to assure proper seeding of the nitrification bioreactor. These booster inoculations may be continuing for the first month of operation or may continued until determined unnecessary. Assuming a 30 gallon bioreactor between about 100 ml to about 150 ml of about 20x concentrated liquid nitrifying consortium may be pumped via the inoculating booster pump through the inoculating booster port into the bioreactor up to 10 times a day. If a less concentrated nitrifying consortium is used a proportional amount of nitrifying consortium should be used.

In operation, the potable water delivered to the bioreactor each day should be set from about 1 to about 1/12 of the total volume of the bioreactor, preferably from about 1/2 to about 1/9 of the total volume of the bioreactor, more preferably about 1/7 of the total volume of the bioreactor. The temperature of the bioreactor is set on a heater and should be from about 60 degrees F to about 120 degrees F, preferably from about 80 degrees F to about 100 degrees F.

The process may be initiated by starting water and nutrient flow to the bioreactor. For instance, by cycling the nutrient and water pumps enough times to fill the bioreactor. This, along with the heat and aeration, will start the germination process. After initiation, there will be copious bubbling of the composition in the bioreactor, now inoculated with microbes. The resulting aeration aids the overall growth and colonization of the nitrification microorganisms. In time, the microorganism substrate utilization rates (of nitrogen, and also protein and carbohydrates) approach that of delivery rates. The organization of the microorganism consortium will in general continually tend to improve overall over time as the microorganisms co-adapt to maximize target type nitrogen utilization.

The process of the invention involves pumping of nutrients from the nutrient container by a nutrient pumping means into the bioreactor nitrifier via tubes or pipes. Water is

pumped to the bioreactor nitrifier, thus displacing microbes, organic and inorganic nutrients and bacterial products into a dosing tank that will be dosed toward the environment to be treated. This discharge may be timed and/or suitably regulated. The cycle then repeats according to intervals set on the timer(s).

In preparing the bioreactor for the process of the instant invention, the bioreactor compartment is sterilized by cleaning it with, or otherwise applying, a suitable disinfectant agent to the surface. For instance, a 70% ethanol solution, or some similar alcohol based surface active disinfectant may be used. After the bioreactor has been suitably sterilized, a suspended bacterial product, either in desiccated or in liquid quiescent-like form, is added to the bioreactor compartment. Preferably, the bacterial product is enclosed in a 1/16 inch steel mesh ball, and contains from about 1 to about 15 grams of a nitrifying microorganism composition. The bioreactor is then sealed and all connections are capped off until after installation.

The nitrifying and facultative anaerobic de-nitrifying microorganisms employed in the starter material may vary upon the type and concentration of nitrogen-based waste in the environment to be treated. In one embodiment, where the microorganisms are used to degrade ammonia from animal feces and urine, the starter material contains at least one microorganism selected from the group consisting essentially of Nitrosomonas, Nitrosuspira, Nitrosolobus, Nitrococcus, and Nitrobacter. The bacterial product that may be employed contains non-pathogenic microorganisms capable of digesting ammonia and nitrogenous waste found in animal urine and feces. The starter mixture will also contain heterotrophs. The content and concentration of the inorganic and organic nutrients in the food will vary with the type of microorganism used in the apparatus.

Media A can be prepared by mixing $(\text{NH}_4)_2\text{SO}_4$; K_2HPO_4 ; Fe ; MgSO_4 ; CaCl_2 ; EDTA; and trace elements that include but are not limited to CuSO_4 , Co(II)Cl , Molybolic acid,

MnCl₂·7H₂O, and ZnSO₄ in a mixing kettle. After all ingredients are added the mixture is autoclaved.

Media B can be prepared by mixing KHCO₃; a sugar source (*e.g.* dextrose); and an amino acid source (*e.g.* peptone) in a mixing kettle. After all ingredients are added the mixture is filtered sterilized.

As explained above, when the composition is used as a starter material, at least one nitrifying microorganism is added. The nitrifying microorganism may be selected from the group of microorganisms Nitrosomonas, Nitrosuspira, Nitrosolobus, Nitrococcus, and Nitrobacter and may be added prior to inoculation of the bioreactor. It is within the scope of the invention to substitute microorganism not listed that are capable of digesting waste.

Both the organic digesting microorganism bioreactor and the nitrifier use potable water in growing and dosing microorganisms to the environment to be treated. It is important to assure that the potable water entering the bioreactors is sterile so as not to contaminant the bioreactors with unwanted microorganisms. Therefore, the portable/mobile wastewater treatment system collects potable water into a reservoir and sterilizes the water before it is pumped to either of the bioreactors.

A potable water reservoir and volume regulator provides a regulated acclimatized supply of water for bioreactor. The reservoir and regulator also may operate to dampen external pressure events, isolate the potable water supply, and/or regulate the volume of water provided to the both bioreactor systems through one or more pumps provided by the controller. The potable water reservoir includes a nitrifier and connecting tubes and/or pipes for communication with one or more pump and with the solenoid, and optionally may include a level sensor. The potable water reservoir may also include an air gap for overflow to the atmosphere, and the reservoir and regulator may also be equipped with a water filtration device for preconditioning and/or microbial removal from the source water.

The portable/mobile wastewater treatment unit may also include a re-circulating pump. The waste from a pre-determined location within the environment to be treated enters the re-circulating pump through the intake hose that is in fluid communication with the environment to be treated. The waste exits the re-circulating pump at the opposite end into a hose that is in fluid communication with the environment to be treated. The exiting waste is then augmented with oxygen and microorganisms from the dosing tank. In the case where the environment to be treated is a lagoon, circulation of the waste water will help float solids so that the solids are more accessible to the microorganisms and added dissolved oxygen into the lagoon. Adding a restriction nozzle to the effluent flow of the re-circulating pump can increase adding dissolved oxygen.

In one embodiment the re-circulating pump is between about 5 to about 15 HP trash pump made by Vaughan Co., Inc. of Montesano, WA or CH & E, Corporation of Milwaukee, Wisconsin, or Gorman Rupp, Corporation of Cleveland Ohio.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a top down view of a cutaway diagram of one embodiment of the invention.

Figure 2 illustrates one embodiment of the wheeled container.

Figure 3 illustrates one embodiment of the manifold system attached to the portable/mobile wastewater bio-augmentation system.

DETAILED IDENTIFICATION OF THE COMPONENTS IN THE FIGURES

- 10) Portable/mobile wastewater Bio-Augmentation System
- 15) Nutrient container for bioreactor 1 & 2
- 20) Nutrient container for Nitrifier bioreactor

- 25) Refrigerator For Nitrifier Booster Inoculants
- 30) Nitrifier Booster Inoculant
- 35) Pump For Nitrifier Booster Inoculant
- 40) Nitrifier bioreactor
- 45) Nutrient Tube/Pipe
- 50) Bioreactor 1
- 55) Nitrifier Dosing Tube/Pipe connecting nitrifier with dosing pump
- 60) Nitrifier Dosing Tube/Pipe
- 65) Dosing Tank
- 70) Nitrifier Dosing Pump
- 75) Bioreactor 1 Dosing Tube/Pipe
- 80) Bioreactor 2 Dosing Tube/Pipe
- 85) Water Pump
- 90) Sterilizer
- 95) Water Tube/Pipe
- 100) Bioreactor 2 Nutrient Pump
- 105) Sterilizer
- 110) Water Tube/Pipe
- 115) Nitrifier Nutrient Pump
- 120) Bioreactor 2
- 125) Water Tube/Pipe for Bioreactor 2
- 130) Water Pump
- 135) Water Reservoir
- 140) Water Pipe/Tube into Reservoir
- 145) Inflow for Reservoir

- 150) Intake Tube/Pipe for re-circulation Pump
- 155) Portable/mobile Vehicle
- 160) Re-circulation Pump
- 165) Nose of Portable/mobile Vehicle
- 170) Trailer Hitch
- 175) Controller
- 180) Electrical Panel
- 185) Outflow pipe/tube from Re-circulation Pump
- 190) Outflow Nozzle
- 195) Dosing injection Tube/Pipe
- 200) Water Pump Tube/Pipe
- 205) Electrical Power Cord
- 210) Bioreactor 1 Nutrient Pump
- 215) Wireless remote transmitter

Figure 3

- 300) Floating Dock Strainer (Suction)
- 305) 4" Actuator Valve
- 310) 2" Actuator Valve
- 315) Big Gun Irrigation Sprinkler
- 320) PVC Ball Valve
- 325) Eductor Nozzle
- 330) Flexible Suction Hose
- 335) PVC Spray Pipe
- 340) PVC Sub-Surface Pipe
- 345) PVC Distributor Pipe

- 350) Reducer Bushing
- 355) Marine Bumpers
- 360) Portable/mobile Bio-Augmentation Unit
- 365) Treated Support for Sprinklers

DETAILED DESCRIPTION OF THE DRAWINGS

As illustrated in Figures 1 through 2, the apparatus comprises six main subsystems: a portable/mobile wheeled container (155); a controller unit (175); a bio-augmentation system for growing organic digesting microorganisms; a bio-augmentation system for growing nitrifying microorganisms; potable water reservoir and regulator (135); and a recirculation pump (160).

One embodiment of the invention is shown in Figure 1. Potable water enters the portable/mobile bio-augmentation unit (10) through water pipe/tube (140) into water reservoir (135). The water reservoir (135) is in fluid communication with bioreactor 1 (50) and bioreactor 2 (120) as well as the nitrifier bioreactor (40). Before water enters any of the bioreactors it passes through either sterilizer (90) or (105). The sterilizers can use ultra-violent light (UV), radiation or any other method of sterilization known in the art. Once sterilized, the water enters bioreactor 1 (50) via water pump (130) and bioreactor 2 (120) via water pump (200). The pumps are controlled either by the controller (175) and/or timers (not shown). The composition in bioreactor 1 (50) and bioreactor 2 (120) is displaced through bioreactor 1 dosing tube/pipe (75) and bioreactor 2 dosing tube/pipe (80) into dosing tank (65). Once the composition from the bioreactors comprising activated organic digesting microorganisms enters into the dosing tank the negative suction created from the re-circulating pump (160) draws the microorganism composition out of the tank and dispenses the microorganisms to the environment to be treated.

A similar protocol is followed with the dosing of the nitrifier bioreactor (40). Once sterilized, the water enters the nitrifier bioreactor (40) water pump tube/pipe (200) via water pump (130). The pump is controlled either by the controller (175) and/or timers (not shown). The composition in the nitrifier bioreactor (40) is displaced through nitrifier dosing tube/pipe (55) into dosing tank (65). Once the composition from the nitrifier bioreactor (40) comprising activated nitrifying microorganisms enters into the dosing tank the negative suction created from the re-circulating pump (160) draws the microorganism composition out of the tank and dispenses the microorganisms to the environment to be treated.

Booster nitrifier inoculant (30) may be refrigerated in refrigerator (25) and periodically dosed into the nitrifier bioreactor (40) via pump (35) according to a predetermined schedule or when the pH of the nitrifier bioreactor (40) dips below a predetermined pH. Either the controller or an independent timer may control the pumps. The nitrifier bioreactor (40) is fed nitrifier nutrients from the nutrient container for the nitrifier bioreactor (20). These nutrients are effective in getting the nitrifying microorganisms into the activated log-growth phase. The nutrients are dispensed to the nitrifier bioreactor (40) according to a predetermined schedule and may be controlled by either the controller or an independent timer.

The re-circulation pump (160) has an inflow (145) connected to an intake tube/pipe (150) that supplies the re-circulating pump (160) with liquid from the environment being treated. The re-circulating pump (160) releases the contaminated liquid through the outflow pipe/tube (185) out the outflow nozzle (190) into the environment to be treated. The outflow nozzle (190) may be equipped with a restriction device that increase the amount of dissolved oxygen in the contaminant flow so that additional oxygen is delivered to the environment to be treated aiding in the oxidative digestion of the organic material in the contaminated site. The operation of the re-circulating pump may be connected to the

controller (175) that controls the activation and de-activation of the re-circulating pump (160).

In one embodiment of the present invention, the portable/mobile wastewater bio-augmentation system may contain a wireless transmitting device (215) that is connected to the controller (175). The controller (175) may be equipped connected to sensors (not shown) dispersed throughout the environment to be treated as well as on the internal components of the portable/mobile wastewater bio-augmentation system (10). For example, the bioreactors may be equipped with a pH sensor that feeds data points to the controller (175) that can be sent to a remote location, cell phone, and or pager when they fall outside of a pre-determined range.

The biomass that is released to the environment to be treated may comprise a self-inoculating bio-film. The bio-film released from the bioreactor comprises a highly concentrated number of bacterial colonies that are acclimated to the environment to be treated and are in logarithmic growth phase. For the purpose of this patent, a colony should be understood to mean a plurality of bacterial cells aggregated together as a unit compared to the same number of bacterial cells existing independently.

As stated above, the bio-film that is produced in the bioreactor may be produced on a bio-mesh or any other internal surface of the bioreactor. A bio-mesh is a network of filaments aggregated together to provide an increased ratio of surface area to volume. As the bioreactor doses bacteria to the environment to be treated only a portion of the bio-film is released into the environment to be treated leaving behind the mother load of bacterium which continues to multiply and provide high volumes of bacterium.

Figure 3 shows one variation of a distributor/delivery manifold system (375) of the present invention. The manifold system configuration may vary according to the configuration of the environment being treated. Although the actual configuration of the

manifold system may change, the fundamental components remain the same. The manifold system shown in figure 3 has a floating dock (300) that can be used to take test samples and support a flexible suction hose (330). The flexible suction hose (330) is connected to the portable/mobile bio-augmentation unit (360) at one end, fastened to the floating dock (300) in the middle and terminates in the environment to be treated. The suction hose (330) brings waste from the environment to be treated to the portable/mobile bio-augmentation unit (360) where it is re-circulated out the outflow hose (370) and back into the environment to be treated.

The re-circulated waste travels out the outflow hose (370) to the PVC manifold through actuator valves (305) and (310). The actuator valves (305) and (310) can be closed when the unit is not in operation so as to prevent back-ups. The manifold system (375) also has a PVC spray pipe (335) that is attached to several treated posts (365) located at several different points of the environment to be treated. The posts are used for support. At each post the PVC pipe is attached to a big gun Irrigation sprinkler (315) that sprays between 80 and 100 gallons of re-circulated waste per minute in a 90 to about 105 degree radius. The spray pipe (335) is fitted at the end of a section with a PVC Ball Valve (320) that regulates the flow and pressure of the system.

The outflow hose (370) is also connected to a sub-surface PVC Pipe (340) that spans at least a portion of the environment to be treated. The sub-surface PVC Pipe (340) is connected to several reducer bushings (350). Connected to each reducer bushing (350) is a PVC distributor pipe (345) that terminates with an eductor nozzle (325). The eductor nozzles (325) mix between 1 to about 5 gallons per minute of re-circulated waste that has been oxygenated and injected with microorganisms from the nitrifier unit and/or bioreactors of the portable/mobile bio-augmentation unit (360) back into the environment to

be treated. The sub-surface PVC Pipe (340) is fitted at the end of each section with a PVC Ball Valve (320) that regulates the flow and pressure of the system.

The manifold system (375) described above is only one design that can be used with the present invention. It is understood that one skilled in the art would be able to design a variation of the manifold to achieve the same basic principle, distributing and delivering the bio-augmentation composition to the environment to be treated. These variations on this basic manifold system are contemplated as being part of the present invention. The exact configuration is not critical to the invention.

While the invention has been illustrated and described with respect to specific illustrative embodiments and modes of practice, it will be apparent to those skilled in the art that various modifications and improvements may be made without departing from the scope and spirit of the invention. Accordingly, the invention is not to be limited by the illustrative embodiment and modes of practice.

What is claimed is:

1) A portable/mobile apparatus for delivering microorganisms to an environment to be treated comprising:

a structure having an interior space;

a bioreactor vessel having a bioreactor output port, said bioreactor vessel positioned within said structure;

a nutrient container comprising a mixture of inorganic and organic nutrients, said nutrient container positioned within said structure;

a nutrient pumping means for pumping inorganic and organic nutrients from said nutrient container to said bioreactor;

a water pumping means for pumping water into said bioreactor, said water pumping means is in fluid communication with said bioreactor and a water source wherein said water pumped into the bioreactor displaces fluid out of said bioreactor output port;

a recirculation pump positioned within said structure, said recirculation pump is in fluid communication with said environment to be treated; and

a controller in communication with said recirculation pump, said nutrient pumping means, and said water-pumping means, said controller activating and deactivating said recirculation pump, said nutrient pumping means, and said water pumping means according to a predetermined schedule.

2. The portable/mobile apparatus for delivering microorganisms to an environment to be treated according to claim 1 further comprising:

a nitrifier unit comprising at least three connection ports and a nitrifier recirculation tube exiting one portion of said nitrifier and entering a different portion of said nitrifier, said nitrifier unit positioned within said structure;

a nitrifier recirculation pump in communication with said nitrifier recirculation tube;

an output tube connected to a first connection port on said nitrifier unit wherein effluent is released;

a nutrient dispenser connected to a second connection port on said nitrifier unit and a dispensing pump, said nutrient dispenser and dispensing pump positioned within said structure;

a water tube connected to a third connection port on said nitrifier unit at one end of the water tube and a water supply at the other of the water tube;

a water pumping means for pumping water into said nitrifier unit, said water pumping means is in fluid communication with said nitrifier unit and a water source wherein said water pumped into said nitrifier unit displaces fluid out of said output tube of said nitrifier unit; and

a controller in communication with said nitrifier recirculation pump, said dispensing pump and said water pumping means, said controller activates said recirculation pump, said dispensing pump and said water pumping means according to a predetermined schedule.

3. The portable/mobile apparatus for delivering microorganisms to an environment to be treated according to claim 2, wherein said output tube of said bioreactor and said nitrifier unit is in fluid communication with said recirculation pump so that the effluent of said bioreactor and said nitrifier unit mixes with said recirculation flow and are dosed into the environment to be treated.

4. The portable/mobile apparatus for delivering microorganisms to an environment to be treated according to claim 2, further comprising at least one heater means in said bioreactor and at least one heater means in said nitrifier unit for heating said bioreactor and said nitrifier unit.
5. The portable/mobile apparatus for delivering microorganisms to an environment to be treated according to claim 2, wherein said nutrient pumping means, said nutrient dispenser, and said water pumping means are pneumatic pumps.
6. The portable/mobile apparatus for delivering microorganisms to an environment to be treated according to claim 2 wherein said controller comprises a programmable memory and an actuator, said controller being in communication with said nitrifier recirculation pump, said nutrient dispensing pump of said nitrifier unit, said water pumping means of said nitrifier unit, said recirculation pump, said nutrient pumping means of said bioreactor, and said water pumping means of said bioreactor wherein the actuator activates said nitrifier recirculation pump, said nutrient dispensing pump of said nitrifier unit, said water pumping means of said nitrifier unit, said recirculation pump, said nutrient pumping means of said bioreactor, and said water pumping means of said bioreactor according to a predetermined schedule stored in the programmable memory of the controller.
7. A portable/mobile apparatus for delivering microorganisms to an environment to be treated comprising:

a structure having an interior space;

a bioreactor vessel having a bioreactor output port, said bioreactor vessel positioned within said structure;

a nutrient container comprising a mixture of inorganic and organic nutrients, said nutrient container positioned within said structure;

a nutrient pumping means for pumping inorganic and organic nutrients from said nutrient container to said bioreactor;

a solenoid in fluid communication with a water supply and said bioreactor, the solenoid having an open and closed position wherein water flows into the bioreactor from the water supply when said solenoid is in the open position and water is prevented from entering into the bioreactor from said water supply when said solenoid is in the closed position and wherein said water entering said bioreactor displaces fluid out of said output port on said bioreactor;

a recirculation pump positioned within said structure, said recirculation pump is in fluid communication with said environment to be treated; and

a controller in communication with said recirculation pump, said nutrient pumping means, and said water pumping means, said controller activates and deactivates said recirculation pump, said nutrient pumping means, and opens and closed said solenoid according to a predetermined schedule.

8. The portable/mobile apparatus for delivering microorganisms to an environment to be treated according to claim 7 further comprising:

- a nitrifier unit comprising at least three connection ports and a nitrifier recirculation tube exiting one portion of said nitrifier and entering a different portion of said nitrifier, said nitrifier unit positioned within said structure;
- a nitrifier recirculation pump in communication with said nitrifier recirculation tube;
- an output tube connected to a first connection port on said nitrifier unit wherein effluent is released;
- a nutrient dispenser connected to a second connection port on said nitrifier unit and a dispensing pump, said nutrient dispenser and dispensing pump positioned within said structure;
- a water tube connected to a third connection port on said nitrifier unit at one end of the water tube and a water supply at the other of the water tube;
- a solenoid in fluid communication with a water supply and said nitrifier unit, said solenoid having an open and closed position wherein water flows into said nitrifier unit from said water supply when said solenoid is in the open position and water is prevented from entering into said nitrifier unit from said water supply when said solenoid is in the closed position and wherein said water entering said nitrifier displaces fluid out of said output port on said nitrifier unit ;
- a recirculation pump positioned within said structure, said recirculation pump is in fluid communication with said environment to be treated; and
- a controller in communication with said nitrifier recirculation pump, said dispensing pump and said solenoid, said controller activates said recirculation pump, said dispensing pump and opens and closes said solenoid according to a predetermined schedule.
9. The portable/mobile apparatus for delivering microorganisms to an environment to be treated according to claim 8, wherein said output tube of said bioreactor and

said nitrifier unit is in fluid communication with said recirculation pump so that the effluent of said bioreactor and said nitrifier unit mixes with said recirculation flow and are dosed into the environment to be treated.

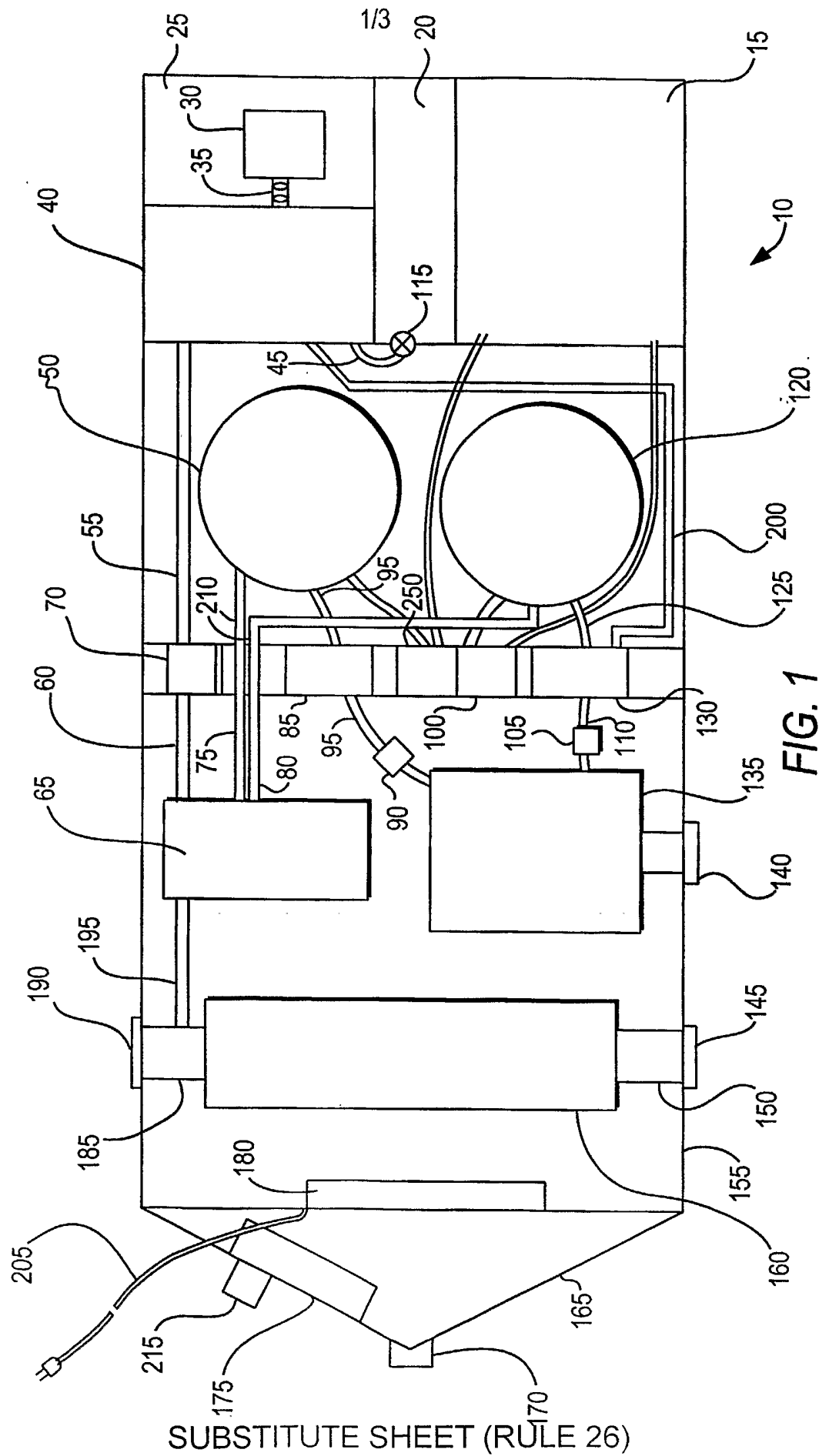
10. The portable/mobile apparatus for delivering microorganisms to an environment to be treated according to claim 9, further comprising at least one heater means in said bioreactor and at least one heater means in said nitrifier unit for heating said bioreactor and said nitrifier unit.

11. The portable/mobile apparatus for delivering microorganisms to an environment to be treated according to claim 8, wherein said nutrient pumping means, and said nutrient dispenser are pneumatic pumps.

12. The portable/mobile apparatus for delivering microorganisms to an environment to be treated according to claim 8, wherein said controller comprises a programmable memory and an actuator, said controller being in communication with said nitrifier recirculation pump, said nutrient dispensing pump of said nitrifier unit, said solenoid of said nitrifier unit, said recirculation pump, said nutrient pumping means of said bioreactor, and said water pumping means of said bioreactor wherein the actuator activates said nitrifier recirculation pump, said nutrient dispensing pump of said nitrifier unit, said water pumping means of said nitrifier unit, said recirculation pump, said nutrient pumping means of said bioreactor, and said water pumping means of said bioreactor according to a predetermined schedule stored in the programmable memory of the controller.

13. The portable/mobile apparatus for delivering microorganisms to an environment to be treated according to claim 2, further comprising a plurality of wheels for easy transportation from on place to another.

14. The portable/mobile apparatus for delivering microorganisms to an environment to be treated according to claim 8 further comprising a plurality of wheels for easy transportation from on place to another.



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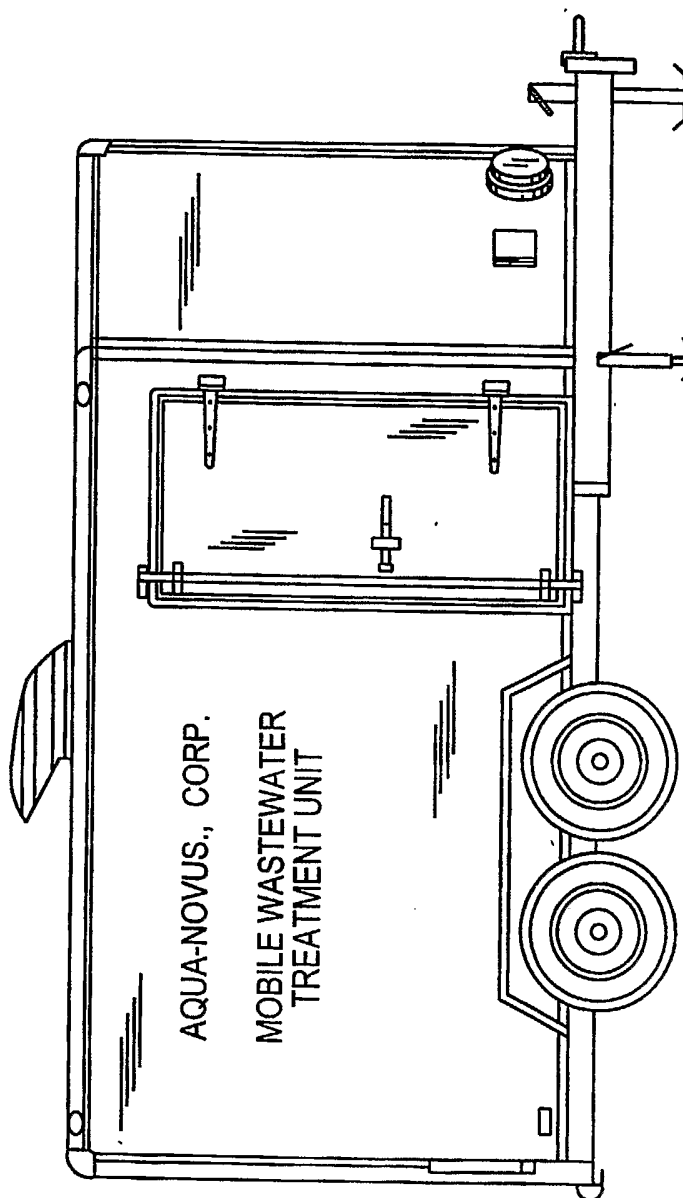


FIG. 2

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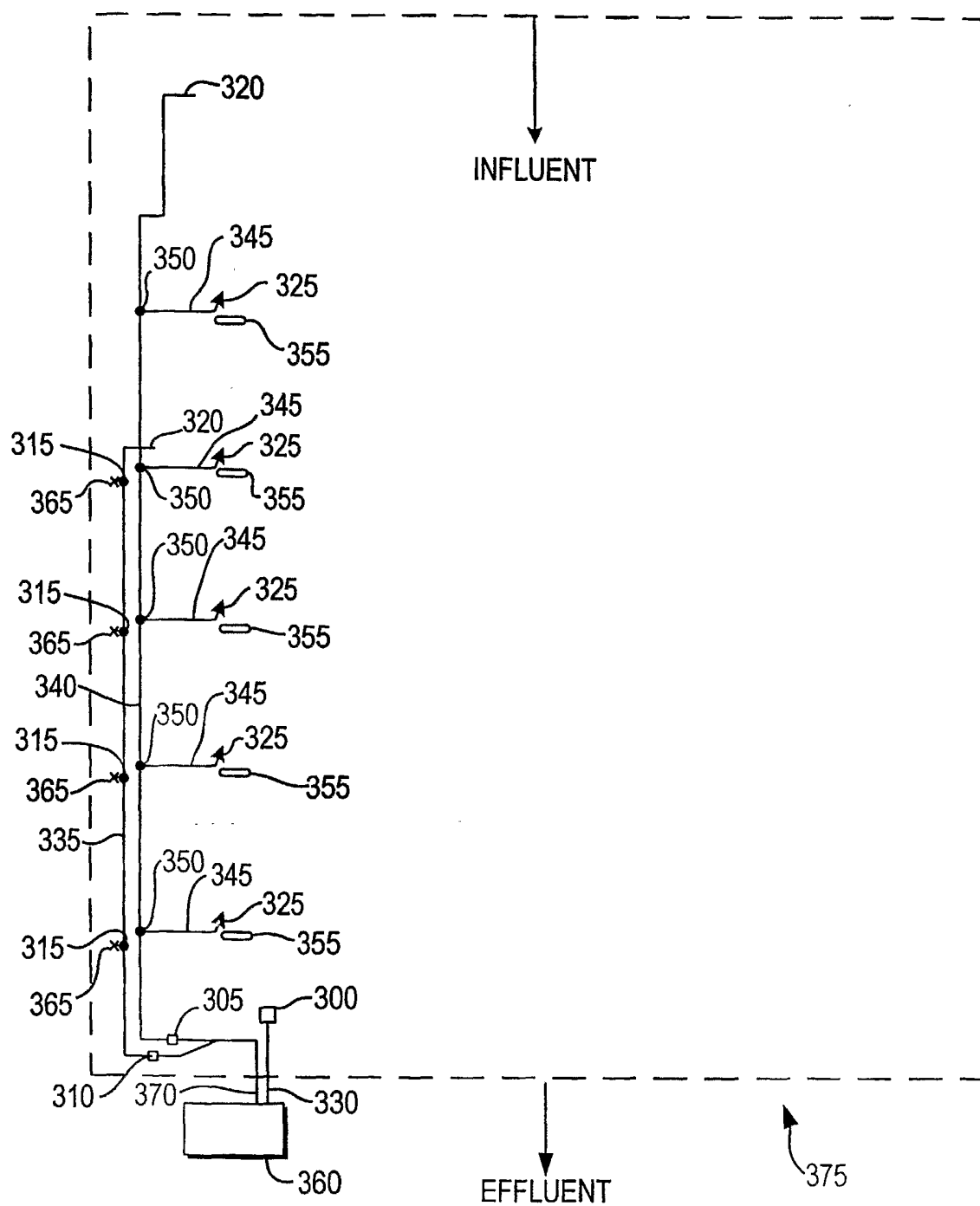


FIG. 3