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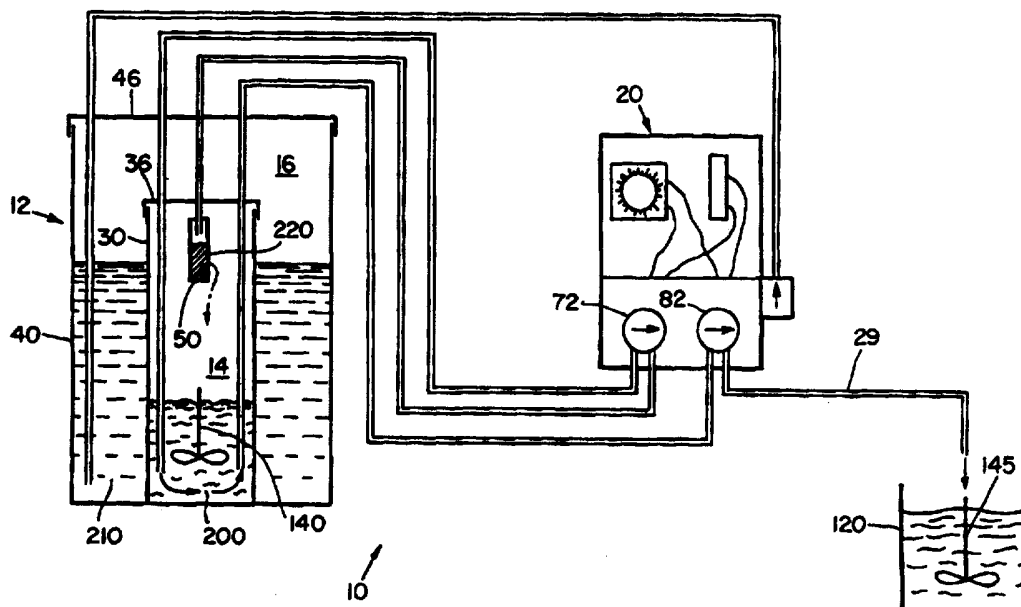
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(54) Title: APPARATUS AND METHOD FOR BIOLOGICAL PURIFICATION OF WASTES



(57) Abstract

An apparatus and method for containing a microorganism culture in exponential growth and delivering a supply of microorganisms to an environment for waste biodegradation. The apparatus has a bioreactor (12) and a controller (20). The bioreactor has a first chamber for containing a supply of microorganisms (14), a second chamber for containing water and inorganic nutrients (16), and a third chamber for containing organic nutrients (50). The controller has a timer and regulator to control pumps (72, 82).

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APPARATUS AND METHOD FOR BIOLOGICAL PURIFICATION OF
WASTES

BACKGROUND OF THE INVENTION

5 The present invention relates to an apparatus and method for biological purification of wastes. More particularly, the invention is directed to an apparatus and method for treatment of wastes, such as grease and other contaminants contained in waste water streams,
10 ground water, soil, etc., by introducing living organisms to biodegrade the wastes.

 Wastes, under normal conditions, are gradually broken down or biodegraded by indigenous microorganisms in the environment. However, biodegradation reactions
15 are often hindered by environmental fluctuations such as changes in temperature, pH, salinity, water and air supply, etc. Microorganisms break down wastes consisting of fat and grease to fatty acids and glycerol. In the presence of oxygen the fatty acids are further
20 metabolized with the end product being carbon dioxide. Glycerol is also metabolized as an efficient energy source.

 With reference to waste water systems, particularly those in the food service industry typically incorporate
25 a grease trap to trap grease and other contaminants from the passing flow of waste water and store such contaminants for eventual removal from the trap. Typically, the grease trap is accessed periodically and the contaminants removed for eventual disposal. Grease
30 and other contaminants often build up very quickly in such traps. If they are not removed in a timely fashion, the ability of the trap to operate efficiently, or at all, is seriously affected. When a trap is no longer functional, the contaminants will bypass the trap and
35 flow into areas which are intended to be free from these contaminants. Specifically, the contaminants will either clog up the waste water system or will flow into the municipal sewer system in violation of local ordinances or state laws. Most grease traps require relatively

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large compartments, particularly if the food service facility operates on a large volume.

A variety of approaches have been developed to increase the required period between subsequent cleanings of a grease trap by increasing the biodegradation of grease in the trap. One approach to enhance biodegradation of grease in a grease trap is to introduce chemicals or nutrients to the trap to aid naturally occurring bacteria or microorganisms in the trap biodegrade the grease. For example, U.S. Patent No. 5,340,376 granted to Cunningham discloses a controlled-release nutrient source that adds nutrients at low levels to a bioremediation environment to enhance microorganism growth and activity and promote the effectiveness of the bioremediation in removing environmental contaminants. The nutrients are in the form of coated solid particles, each having a core of water soluble microorganism nutrients encapsulated in a release rate-controlling coating. The effectiveness of enhancing the growth of naturally occurring bacteria or microorganisms by introduction of a controlled-release nutrient source is still limited due to environmental fluctuations such as changes in temperature, pH, salinity, water and air supply, etc.

Another approach to enhance biodegradation of grease in a grease trap is to introduce a structure upon which indigenous microorganisms can bind and grow, and thus effectively remain in the grease trap. For example, U.S. Patent No. 4,925,564 and U.S. Patent No. 4,670,149 both granted to Francis disclose a bacterial incubator device having an enclosure with a foraminous wall structure packed with high surface area elements such as spherical packing of a shape or size to multiply the solid bacterial growth surface area in a grease trap. The incubator is positioned at the interface of floating grease and water. The effectiveness of enhancing the growth of naturally occurring bacteria or microorganisms by introduction of a support structure is still limited

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due to environmental fluctuations such as changes in temperature, pH, salinity, water and air supply, etc.

Still another approach to enhance biodegradation of grease in a grease trap is to introduce additional microorganisms into the grease trap. For example, U.S. Patent No. 5,271,829 granted to Heppenstall discloses a treatment system for waste water which includes a dispenser for introducing treatment material, a solution of bacteria, into a grease trap for the purpose of digesting the grease which is separated from waste water as it flows through the grease trap. The dispenser includes a housing having a compartment for holding a quantity of grease digesting material and a dispensing opening at the lower end of the compartment. A restrictor is located at the dispensing opening for enabling the digesting material to pass at a constant restrictive rate from the dispensing opening to the grease to be treated in the chamber of the grease trap. The grease digesting material will naturally go through a four phase growth cycle (i.e., lag, exponential, stationary, and death, further described in detail in a Bacterial Growth Section below) which limits its effectiveness of enhancing the biodegradation of the grease on an extended or continuous basis.

Another example of introducing additional microorganisms in to a grease trap is U.S. Patent No. 5,225,083 granted to Pappas, et al. Pappas, et al. discloses a simple method that includes adding endemic bacterial microorganisms to one or more of the drain lines for ultimate introduction into the grease trap and biodegrading grease. Again, the bacterial microorganisms when introduced, depending on where they are along their growth cycle, will vary the effectiveness of the biodegradation of grease by the microorganisms.

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Another approach to enhance biodegradation of grease in a grease trap is to introduce enzymes into the grease trap to solubilize the grease. For example U.S. Patent No. 4,940,539 granted to Weber discloses a grease trap comprising a housing having an inlet to receive waste water containing grease and an outlet. The waste water within the housing is heated by an electric heating element which is immersed in the waste water and the heating element is controlled by a thermostat to maintain a desired temperature of the water within a given range. An aqueous composition containing a mixture of enzymes and bacterial spores is introduced into the housing into contact with the waste water. The enzymes solubilize the grease while the bacteria spores biodegrade the grease. However, the bacterial spores require a period of time during their lag phase growth before entering an exponential growth phase in which to begin biodegrading the grease.

Another example, U.S. Patent No. 4,882,059 granted to Wong, et al. discloses a method for solubilizing particulate materials in waste water which comprises the steps of cultivating aerobic bacteria in the presence of oxygen in an activator solution containing a food source until the level of the food source drops below a predetermined level causing the bacteria to begin producing increased amounts of enzymes and thereafter contacting the activated bacteria and enzymes with the particulate materials under conditions which solubilize the waste. Another example, shown in U.S. Patent No. 5,171,687 granted to Moller, et al., discloses an apparatus for culturing and delivering microbes for waste treatment in a flow system. The apparatus includes a container having a first and second chambers. The first chamber is maintained in a nutrient rich environment for the source microbial matter supported therein while the second chamber is nutrient deficient. Water is introduced into the first chamber at a predetermined rate and flows through an outlet into the second chamber. The

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outlet of the second chamber is directed to a flow system benefiting from the activity of the microbial matter. In both Wong and Moller, et al., it is believed that starving the bacteria of nutrients activates enzyme
5 production therein to aid in solubilizing particulate materials in waste water. Although, the enzymes aid in solubilizing the grease, the bacteria will be ineffective in biodegrading the solubilized grease in that the bacteria being nutrient deficient will enter a stationary
10 phase (if not death phase) and require a period of time to re-enter the lag phase then exponential growth phase in order for the bacteria to begin to biodegrade the grease.

There is a need for a bio-augmentation system that
15 maintains preselected grease digesting microorganisms in an active exponential growth phase and at a level known to provide a predetermined concentration, desirably a maximum concentration, of the active microorganisms and that is further capable of delivering active
20 microorganisms on a continuous or periodic basis to an environment containing wastes for effectively bio-augmenting the biodegradation of the wastes contained in the environment.

25 SUMMARY OF THE INVENTION

Accordingly it is an object of the present invention to provide, in a waste treatment facility, a bio-augmentation system that adjusts the environment to be
30 treated to a condition that is more conducive to biodegradation of the treated waste by introduction of preselected and acclimated bacteria or microorganisms designed for that purpose.

It is another object of the present invention to
35 provide a bio-augmentation system that maintains selected microorganisms in an active exponential growth and acclimated to an environment to be delivered, and deliver

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the microorganisms to an environment containing wastes for efficiently and quickly biodegrading the wastes.

It is also an object of the present invention to provide a bio-augmentation system that introduces
5 microorganisms into an environment to be treated to ensure long-term maintaining, supplementing, and reconditioning of the biodegradation process for peak performance or restarting the biodegradation process should the normal rate of biodegradation stall in the
10 environment to be treated.

It is still another object of the present invention to provide a bio-augmentation system that injects microorganisms into a waste flow system, e.g., a grease trap, which greatly increases the normally required time
15 between skimming operations.

It is still another object of the present invention to provide a bio-augmentation system for use in conjunction with a grease trap and which reduces the size of the required grease trap for effectively removing
20 grease from waste water before discharge of the waste water into a municipal sewer system as permitted under local environmental ordinances or state laws.

It is yet another object of the present invention to provide a bio-augmentation system for use in waste
25 treatment in which the system overcomes the problems associated with environmental fluctuations such as changes in temperature, pH, salinity, water and air supplies, etc. which limit the indigenous microorganisms ability to biodegrade wastes.

It is still yet another object of the present
30 invention to provide a bio-augmentation system for use with various waste treatment facilities, such as drain lines, leach ponds, septic systems and lift stations, for bio-remediating waste water streams, and ground water and
35 soil contamination.

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It is a further object of the present invention to provide a bio-augmentation system for biological purification of wastes which is simple in construction and which is inexpensive, and which is capable of a long
5 life of useful service with a minimum of maintenance.

It is an object of the present invention to provide a method for culturing and delivering microorganisms in exponential growth to an environment for biodegradation of wastes contained in the environment.

10 Certain of the foregoing and related objects are readily obtained in a bio-augmentation apparatus for containing a microorganism culture and delivering a predetermined supply of microorganisms to an environment containing wastes for bio-augmenting the biodegradation
15 of the wastes, the apparatus comprising a first container having a bioreactor chamber for containing a microorganism culture and a controller. The controller includes means for introducing a predetermined supply of water to the bioreactor chamber, and for introducing a
20 predetermined supply of at least one of inorganic nutrients and organic nutrients to the bioreactor chamber, and means for removing a predetermined supply of water, at least one of inorganic nutrients and organic nutrients, and microorganisms from the bioreactor chamber
25 so that the controller is effective to maintain such microorganisms in substantially exponential growth in the bioreactor chamber, and means for delivering such a removed predetermined supply of water, at least one of inorganic nutrients and organic nutrients, and
30 microorganisms in substantially exponential growth into contact with an environment containing wastes to be biodegraded.

Preferably, the bio-augmentation apparatus includes means for introducing a predetermined supply of oxygen to
35 the bioreactor chamber. Desirably, the means for introducing a predetermined supply of water to the bioreactor chamber, and for introducing a predetermined supply of at least one of inorganic nutrients and organic

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nutrients to the bioreactor chamber, and the means for removing a predetermined supply of water, organic nutrients, and microorganisms from the bioreactor chamber so that the controller is effective to maintain the

5 microorganisms in the bioreactor chamber in substantially exponential growth, is either periodically operable or continuously operable. Advantageously, the means for introducing a predetermined supply of water to the bioreactor chamber, and for introducing a predetermined

10 supply of at least one of inorganic nutrients and organic nutrients to the bioreactor chamber, and the means for removing a predetermined supply of water, at least one of inorganic nutrients and organic nutrients, and microorganisms from the bioreactor chamber, is operable

15 to introduce and remove, respectively, substantially the same volumetric predetermined supplies.

In an preferred embodiment of the present invention, the bio-augmentation apparatus includes a second container having a second chamber for containing a supply

20 water, the second chamber operably connected in fluid communication with the bioreactor chamber, and a third container having a third chamber for containing a supply of organic nutrients, the third chamber operably connected in fluid communication with the bioreactor

25 chamber. The first container includes a circular bottom and an upwardly extending cylindrical side wall, the second container includes a circular bottom and an upwardly extending cylindrical side wall, and the third container includes a circular bottom and an upwardly

30 extending cylindrical side wall.

Desirably, the first container is disposed within the second container, the third container is disposed within the bioreactor chamber, and the second chamber is annular in shape.

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In still a more preferred embodiment of the present invention of the bio-augmentation apparatus, the means for introducing a predetermined supply of water to the bioreactor chamber, and for introducing a predetermined supply of at least one of inorganic nutrients and organic nutrients to the bioreactor chamber, includes a first pump operably connected in fluid communication between the bioreactor chamber and the second chamber, and the means for removing a predetermined supply of water, at least one of inorganic nutrients and organic nutrients, and microorganisms and means for delivering the removed predetermined supply of water, at least one of inorganic nutrients and organic nutrients, and microorganisms into contact with an environment containing wastes to be biodegraded, includes a second pump operably connected in fluid communication between the bioreactor chamber and the environment containing wastes to be biodegraded.

Desirably, the controller includes a timer and a regulator operably connected to the first pump and second pump to effectively maintain the microorganisms in substantially exponential growth in the bioreactor chamber.

Certain of the foregoing and related objects are also readily obtained in a method for bio-augmenting the biodegradation of wastes. The method includes the steps of: providing a microorganism culture, introducing a predetermined supply of water and at least one of inorganic nutrients and organic nutrients to the microorganism culture, removing a predetermined supply of water, at least one of inorganic nutrients and organic nutrients, and microorganisms from the microorganism culture so that the microorganism culture is maintained in substantially exponential growth, and delivering the removed predetermined supply of water, at least one of inorganic nutrients and organic nutrients, and microorganisms into contact with an environment containing a waste for biodegrading the waste.

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Preferably, the microorganisms are at least one of anaerobic and aerobic microorganisms, and the at least one inorganic nutrients and organic nutrients are substantially similar to wastes contained in the waste to be biodegraded so as to acclimate the microorganisms to the waste to be biodegraded. Advantageously, the microorganism culture is maintained in substantially exponential growth midway between a lag phase growth and a stationary growth. Desirably, the microorganism culture is maintained in a bioreactor chamber at a concentration of about 500 million cells/cubic centimeter to about 3 billion cells/cubic centimeter. More desirably, the microorganism culture is maintained in a bioreactor chamber at a concentration of about 2.5 billion cells/cubic centimeter.

Preferably, the step of introducing a predetermined supply of water and at least one of inorganic nutrients and organic nutrients to the microorganisms culture and the step of removing a predetermined supply of water, at least one of inorganic nutrients and organic nutrients, and microorganisms from the microorganism culture so that the microorganism culture is maintained in substantially an exponential growth, are either periodically or continuously performed.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and features of the present invention will become apparent from the following detailed description considered in connection with the accompanying drawings, which disclose several embodiments of the invention. It is to be understood that the drawings are to be used for the purpose of illustration only and not as a definition of the limits of the invention.

In the drawings, similar reference characters denote similar elements throughout the several views:

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FIG. 1 is a perspective view of a preferred embodiment of an apparatus of the present invention which generally includes a bioreactor operably connected to a controller;

5 FIG. 2 is an enlarged perspective view, partially broken away, of the bioreactor of FIG. 1;

FIG. 3 is a graphical representation of a typical four phase growth cycle (i.e., lag, exponential, stationary, and death) of a microorganism culture in
10 which no additional culture medium is added;

FIG. 4 is a diagrammatic illustration of the bio-augmentation apparatus of FIG 1;

FIGS. 5(a) and 5(b) are graphical results using optical density measuring means for periodically sampling
15 (a) a microorganism culture which shows the various lag, exponential and stationary growth cycle phases of the microorganism culture and (b) the microorganism culture maintained in the bio-augmentation system of FIG. 1 in which the microorganism culture is maintained in an
20 exponential growth phase; and

FIG. 6 is a flow chart illustrating the method of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

25

Apparatus

Turning now to the drawings and in particular to FIG. 1, therein illustrated is a bio-augmentation apparatus 10 embodying the present invention. Apparatus
30 10 generally includes a bioreactor 12 for containing a microorganism culture (not shown) in which bioreactor 12 is operably connected to a controller 20 via tubes 22, 24, 26, 28 for effectively maintaining the microorganism culture in an exponential growth and for delivering
35 microorganisms via tube 29 to an environment containing wastes for bio-augmenting the biodegradation of the wastes, e.g., grease in a grease trap or septic tank (not

shown). The operation of apparatus 10 is explained in greater detail in an Operation section below.

Referring to FIG. 2, bioreactor 12 includes a first container 30 having a circular bottom 32 and an upwardly extending cylindrical side wall 34. A removable lid 36 is attached to the upper end of side wall 34 and closes container 30. Surrounding first container 30 is a second container 40 having a circular bottom 42 and an upwardly extending cylindrical side wall 44. A removable lid 46 is attached to the upper end of side wall 44 and closes container 40.

Defined within first container 30 is a cylindrical bioreactor chamber 14 for containing a microorganism culture (not shown). Defined between first container 30 and second container 40 is an annular storage or second chamber 16 for containing a supply of water and generally inorganic nutrients, such as potassium phosphate, ammonium nitrite and calcium chloride.

Preferably, containers 30 and 40 are fabricated from a plastic material that is nontoxic and does not react with the microorganisms, such as polyethylene or polyvinyl chloride. Although bioreactor 12 is shown in a compact configuration, it will be appreciated that containers 30 and 40 can be square or rectangularly shaped and disposed in side by side relationship.

A third container 50 having a third chamber 18, for containing a supply of organic nutrients (not shown) or carbon source such as compacted dry potassium-oleate powder or other water soluble salts of fatty acids, is disposed within bioreactor chamber 14 and supported above the microorganism culture. Desirably, the supply of organic nutrients is similar to that of the waste to be biodegraded so as to acclimate the microorganisms in the microorganism culture (not shown) to the waste to be biodegraded. Specifically, container 50 is cylindrically shaped having an a circular bottom 52 and an upwardly extending cylindrical side wall 54. The upper end of cylindrical side wall 54 receives a rubber stopper 58

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that attaches to tube 26 for receiving a supply of water and inorganic nutrients. A longitudinally extending slit 56 in container 50 permits organic nutrients contained in chamber 18 to be dissolved by a supply of water and inorganic nutrients as they pass through chamber 18 and discharge into bioreactor chamber 14. Again, although bioreactor 12 is shown in a compact configuration, it will be appreciated that container 50 need not be placed inside bioreactor chamber 14 but could consist of a separate stand alone unit or alternatively the supply of organic nutrients could be suitably incorporated in-line with tube 26.

Referring again to FIG. 1, controller 20 effectively maintains the microorganism culture in substantially exponential growth in bioreactor 12 and delivers active microorganisms to an environment to be treated. Specifically, controller 20 controls a predetermined supply of water, inorganic nutrients, organic nutrients and air delivered into bioreactor 12 and a predetermined supply of water, inorganic nutrients, organic nutrients and active microorganisms removed from bioreactor 12.

Means 60 for introducing a predetermined supply of oxygen to bioreactor 12 includes an air pump 62 connected to tube 22. Specifically, tube 22 is connected at one end to air pump 62, and as shown in FIG. 2, the opposite end passes through cover 36 and cover 46 so that the opposite end is positioned adjacent bottom 32 of container 30 in bioreactor chamber 14.

Referring again to FIG. 1, means 70 for introducing a predetermined supply of water (not shown) from second chamber 16 (FIG. 2) to bioreactor 12, and for introducing a predetermined supply of organic nutrients (not shown) from third chamber 18 (FIG. 2) to bioreactor 12, includes a first pump 72, tubes 24 and 26, timer 100 and regulator 110. Specifically, as shown in FIG. 2, tube 24 has a free end disposed adjacent bottom 32 of container 30 for receiving a predetermined supply of water contained in second chamber 16 and the other end of tube 24 is

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attached to an input port on pump 72 (FIG. 1). An output port of pump 72 (FIG. 1) is attached to one end of tube 26 and the opposite end of tube 26 passes through lid 36, lid 46 for connection to stopper 58 in container 50.

5 As shown in FIG. 1, the amount or flow of water removed from second chamber 16 (FIG. 2) and discharged into bioreactor chamber 14 (FIG. 2) is controlled by timer 100 operably connected via wires to pump 72 to turn pump 72 on and off, and regulator 110 is operably
10 connected via wires to pump 72 to adjust the supply of electrical energy to pump 72 thereby to control the speed of pump 72 and thus the flow rate of water when pump 72 is activated. Although, water can be supplied from a municipal water source, it is desirable to include in the
15 supply of water various inorganic nutrients.

Means 80 for removing water, inorganic nutrients, organic nutrients, and microorganisms from bioreactor 12 so as to effectively maintain the remaining microorganism culture in exponential growth includes a second pump 82,
20 tube 28, timer 100 and regulator 110. Specifically, as shown in FIG. 2, tube 28 has a free end disposed adjacent bottom 42 of container 40 for receiving a predetermined supply of water, inorganic nutrients, organic nutrients, and microorganisms contained in bioreactor chamber 14 and
25 an opposite end of tube 28 is attached to an input port on pump 82 (FIG. 1).

Referring again to FIG. 1, means 90 for contacting the removed water, inorganic nutrients, organic nutrients, and microorganisms delivered via tube 28 of
30 means 80 with an environment containing wastes, includes pump 82 and tube 29. Specifically, as shown in FIG. 2, tube 29 has one end attached to an output port on pump 82 (FIG. 1) and an opposite end operably connected to a drain or trap (not shown) for discharging a predetermined
35 amount of the contents of bioreactor chamber 14 containing water, inorganic nutrients, organic nutrients, and microorganisms.

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The amount or flow of water, inorganic nutrients, organic nutrients, and microorganisms, from bioreactor chamber 14 (FIG. 2) to a trap (not shown) is controlled by timer 100 operably connected via wires to pump 82 to turn pump 82 on and off, and regulator 110 operably connected via wires to pump 82 to adjust the supply of electrical energy to pump 82 thereby to control the speed of pump 82 and thus the flow rate of water, inorganic nutrients, organic nutrients, and microorganisms, when pump 82 is activated. Air pump 62, timer 100 and regulator 100 are operably connected to an electrical outlet, preferably 120 volts A.C. (not shown).

Bacterial Growth

A key factor of the present invention is the ability to retain the selected and acclimated microorganism culture in an exponential growth (also known as logarithmic growth) where the microorganisms, i.e., the number of cells, increase in a direct proportion to time or divide at a constant rate, and thus are most active, and to deliver active microorganisms to an environment to be treated.

Specifically, referring to FIG. 3, therein is illustrated a typical growth cycle showing four distinct phases in the cycle of a culture under constant condition, i.e. no additional culture medium (organic and inorganic nutrients) are added for the growth of microorganisms in the culture. The four illustrated growth phases are; lag, exponential, stationary, and death. In the lag phase the number of cells does not increase and the cells are preparing for active growth. Eventually, cell division occurs and an exponential growth phase is reached. Finally, either some nutrients become exhausted or some toxic metabolic products accumulate, and the growth rate decreases and growth ceases.

In the present invention it is desired to retain the selected and acclimated microorganism culture in an

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exponential growth where the microorganisms are most active, and to deliver the active microorganisms to an environment to be treated in which the microorganisms immediately begin to biodegrade the waste.

5 It is not desirable to have the microorganisms delivered to an environment to be treated in which the microorganisms are in a lag phase requiring a period of time before the microorganisms reach an exponential growth phase in which to begin biodegradation of the waste. For example, if the environment to be treated is a grease trap having a periodic or constant fluid flow, the microorganisms will be washed away or removed from the grease trap before being able to biodegrade the waste.

15 Nor is it desirable to have the microorganisms delivered to an environment to be treated in which the microorganisms are in a stationary phase and become stressed which upon delivery of the microorganisms into an environment to be treated require the microorganisms to re-enter a lag phase before entering an exponential growth phase. Again, for example, if the environment to be treated is a typical grease trap having a periodic or constant fluid flow the microorganisms will be washed away or removed from the grease trap before being able to biodegrade the waste.

Operation

The operation of the present invention will be explained with respect to FIG. 4, a diagrammatical illustration of bio-augmentation apparatus 10 for culturing microorganisms in an exponential growth phase and for delivering microorganisms to an environment containing wastes for bio-augmenting the biodegradation of the wastes, e.g., grease in a grease trap 120.

35 In set-up of apparatus 10, covers 36 and 46 of bioreactor 12, shown in place, are removed and an initial microorganism culture 200 consisting of microorganisms and a culture medium of water, inorganic nutrients and

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organic nutrients, is placed in bioreactor chamber 14 of first container 30. Preferably aerobic or anaerobic bacteria, which are either naturally occurring or developed specifically for biodegradation of the specific waste in a environment to be treated, is suitable for use with the present invention.

A supply of water or water and inorganic nutrients 210 is placed in second chamber 16 of second container 40. A supply of dissolvable organic nutrients 220 is packed inside container 50. Covers 36 and 46 are replaced.

The free end of tube 29 is connected to generally the starting point of the waste stream for example a drain (not shown) leading into a grease trap 120 or directly into grease trap 120.

Once the microorganism culture 200 reaches an exponential growth phase, controller 20 is activated to maintain the microorganism culture in exponential growth and deliver microorganisms to an environment to be treated in which the microorganisms are exponentially growing, and thus are at peak performance for biodegrading the waste contained in the environment to be treated.

Referring again to FIG. 4, specifically, controller 20 is set-up to control the rate of water, inorganic nutrients, and organic nutrients into bioreactor chamber 14 and the rate of water, inorganic nutrients, organic nutrients, and microorganisms out of bioreactor chamber 14 and delivered to the environment to be treated, e.g., grease trap 120. A number of variables are involved in maintaining the microorganism culture in an exponential growth phase. Such variables are the type of microorganism and its specific growth rate, the volume of the culture, the initial culture medium, the rate of introduction of water, inorganic nutrients, and organic nutrients into the microorganism culture, and the rate of removal of water, inorganic nutrients, organic nutrients,

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and microorganisms from the microorganism culture which is delivered to an environment to be treated.

Given a certain type of microorganism having a specific growth rate constant, a certain volume of culture, and an initial culture medium, the microorganism culture can be monitored to determine the number of cells in the microorganism culture, i.e, periodically conventionally measuring the optical density of samples of the culture. The microorganism culture will go through a lag phase, exponential phase and stationary phase. By setting-up controller 20, the rate of introduction of water, inorganic nutrients, and organic nutrients into the microorganism culture, and the rate of removal of water, inorganic nutrients, organic nutrients, and microorganisms from the microorganism culture and delivered to an environment to be treated can be adjusted to maintain the microorganism culture in an exponential growth before the microorganism culture reaches the stationary phase.

The rate of introduction of water, inorganic nutrients, and organic nutrients into the microorganism culture, and the rate of removal of water, inorganic nutrients, organic nutrients, and microorganisms from the microorganism culture and delivered to an environment to be treated can be either a continuous rate or accomplished periodically. Desirably, the rate (volume per time) of the introduction and removal will be substantially volumetrically the same whether controller 20 is operated in a continuous or periodic mode. That is, pumps 72 and 82 will be operated simultaneously.

To increase the activity in bioreactor chamber 14, a mixer 140 such as a stirrer or paddle can be operably installed in bioreactor chamber 14. In addition, a mixer 145 such as a stirrer or paddle can also be placed in grease trap 120 to increase the contact of microorganisms to the grease.

Example

Referring to FIG. 5(a), there is graphically illustrated the optical density versus time results of an initial three day experiment that determined the growth cycle of a microorganism culture using optical density measuring means of periodic sampling of the microorganism culture. The microorganism culture consisted of Number 700 bacteria mixture by Sybron Chemicals Inc. A Hewlett Packard 8452A Diode Array Spectrophotometer operating at a 600 nanometer wavelength of light was used to determine the optical density of samples removed from the culture.

Referring now to FIGS. 1 and 5(b), the graphically illustrated results of optical density versus time, for a microorganism culture in bio-augmentation apparatus 10, which after approximately three days, was allowed to reach a cell density midway between its lower and upper exponential growth phase limits as determined and illustrated in FIG. 5(a). Upon the microorganism culture reaching a cell density cell approximately midway between its lower and upper exponential growth phase limits, controller 20 was activated to maintain the microorganism culture at substantially such a cell density and deliver microorganisms to an environment to be treated for a period of over approximately twenty one days.

Referring to FIGS. 4 and 5(b), during the approximately twenty one days, every 4 hours about 200 cubic centimeters of water and inorganic nutrients was added to the microorganism culture and approximately 200 cubic centimeters of water, inorganic nutrients, organic nutrients and microorganisms was removed from the microorganism culture and delivered to a grease trap containing grease to be biodegraded. The water contained inorganic nutrients consisted of potassium phosphate, ammonium nitrite, calcium chloride and magnesium chloride. Specifically, the following is a listing of the relative amounts of water and inorganic nutrients:

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5 H₂O - 1 liter
 KH₂PO₄ - 1 gram
 K₂HPO₄ - 1 gram
 NH₄NO₃ - 1 gram
 CaCl₂ - 0.002 gram
 MgCl₂ - 0.002 gram

10 A typical grease trap 120 without the use of bio-
augmentation apparatus 10 requires grease trap 120 to be
cleaned every 30, and a typical grease trap 120 with the
15 use of bio-augmentation apparatus 10 in operation
requires a grease trap to be cleaned only once a year
(365 days). Preferably, the microorganism culture is
maintained in a bioreactor chamber at a concentration of
about 500 million cells/cubic centimeter to about 3
15 billion cells/cubic centimeter. More preferably the
microorganism culture is maintained in a bioreactor
chamber at a concentration of about 2.5 billion
cells/cubic centimeter.

20 It will be appreciated that microorganism culture
200 can be operated at a greater cell density. However,
operating at too great a cell density risks having the
microorganism culture entering a stationary phase should
not enough water, inorganic nutrients or organic
nutrients be properly introduced. Too low a cell density
25 does not produce enough microorganisms for effective and
optimum biodegrading of wastes. Desirably, a cell
density midway between its lower and upper limits of its
exponential growth phase is chosen and maintained in
bioreactor 12.

30

Method

35 The method according to the present invention for
bio-augmenting the biodegradation of wastes, comprising
the steps of: providing a microorganism culture,
introducing a predetermined supply of water and organic
nutrients to the microorganism culture, removing a
predetermined supply of water, organic nutrients, and
microorganisms from the microorganism culture so that the

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microorganism culture is maintained in a substantially exponential growth, and delivering the removed predetermined supply of water, organic nutrients and microorganisms into contact with an environment
5 containing a waste for biodegrading the waste.

It will be appreciated that the present invention is ideally suitable for use in bio-augmenting the biodegradation of grease in a grease trap, however, the present invention is also amenable to bioremediation of
10 other waste or waste streams such as lagoons, aeration ponds, soil and ground water.

In addition, various means for maintaining and delivering the microorganisms in an exponential growth rate such as electrically or pneumatically operated
15 solenoids or gravity flow means are equally applicable for use in such a bio-augmentation system of the present invention.

While only several embodiments of the present invention have been shown and described, it is obvious
20 that many changes and modification may be made thereunto without departing from the spirit and scope of the invention.

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CLAIMS

1. A bio-augmentation apparatus for containing a microorganism culture and delivering a predetermined supply of microorganisms to an environment containing wastes for bio-augmenting the biodegradation of the wastes, the apparatus comprising:
 - a) a first container having a bioreactor chamber for containing a microorganism culture;
 - b) a controller including,
 - 1) means for introducing a predetermined supply of water to said bioreactor chamber, and for introducing a predetermined supply of at least one of inorganic nutrients and organic nutrients to said bioreactor chamber;
 - 2) means for removing a predetermined supply of water, at least one of inorganic nutrients and organic nutrients, and microorganisms from said bioreactor chamber so that said controller is effective to maintain such microorganisms in substantially exponential growth in said bioreactor chamber; and
 - 3) means for delivering such a removed predetermined supply of water, at least one of inorganic nutrients and organic nutrients and microorganisms in substantially exponential growth into contact with an environment containing wastes to be biodegraded.
2. The bio-augmentation apparatus according to Claim 1, further including means for introducing a predetermined supply of oxygen to said bioreactor chamber.

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3. The bio-augmentation apparatus according to Claim 1, wherein said means for introducing a predetermined supply of water to said bioreactor chamber, and for introducing a predetermined supply of at least one of inorganic nutrients and organic nutrients to said bioreactor chamber, being periodically operable.
4. The bio-augmentation apparatus according to Claim 3, wherein said means for removing a predetermined supply of water, at least one of inorganic nutrients and organic nutrients, and microorganisms from said bioreactor chamber so that said controller is effective to maintain the microorganisms in said bioreactor chamber in substantially exponential growth, being periodically operable.
5. The bio-augmentation apparatus according to Claim 1, wherein said means for introducing a predetermined supply of water to said bioreactor chamber, and for introducing a predetermined supply of at least one of inorganic nutrients and organic nutrients to said bioreactor chamber, being continuously operable.
6. The bio-augmentation apparatus according to Claim 5, wherein said means for removing a predetermined supply of water, at least one of inorganic nutrients and organic nutrients, and microorganisms from said bioreactor chamber so that said controller is effective to maintain the microorganisms in said bioreactor chamber in substantially exponential growth, being continuously operable.

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7. The bio-augmentation apparatus according to Claim 1, wherein said means for introducing a predetermined supply of water to said bioreactor chamber, and for introducing a predetermined supply of at least one of inorganic nutrients and organic nutrients to said bioreactor chamber, and said means for removing a predetermined supply of water, at least one of inorganic nutrients and organic nutrients, and microorganisms from said bioreactor chamber, being operable to introduce and remove, respectively, substantially the same volumetric predetermined supplies.
8. The bio-augmentation apparatus according to Claim 1, further including a second container having a second chamber for containing a supply water, said second chamber operably connected in fluid communication with said bioreactor chamber.
9. The bio-augmentation apparatus according to Claim 10, further including a third container having a third chamber for containing a supply organic nutrients, said third chamber operably connected in fluid communication with said bioreactor chamber.
10. The bio-augmentation apparatus according to Claim 9, wherein said first container includes a circular bottom and an upwardly extending cylindrical side wall.
11. The bio-augmentation apparatus according to Claim 10, wherein said second container includes a circular bottom and an upwardly extending cylindrical side wall.

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12. The bio-augmentation apparatus according to Claim 11, wherein said third container includes a circular bottom and an upwardly extending cylindrical side wall.
13. The bio-augmentation apparatus according to Claim 12, wherein said first container is disposed within said second container.
14. The bio-augmentation apparatus according to Claim 13, wherein said third container is disposed within said bioreactor chamber.
15. The bio-augmentation apparatus according to Claim 14, wherein said second chamber is annular in shape.
16. The bio-augmentation apparatus according to Claim 1, wherein said means for introducing a predetermined supply of water to said bioreactor chamber, and for introducing a predetermined supply of at least one of inorganic nutrients and organic nutrients to said bioreactor chamber, includes a first pump operably connected in fluid communication between said bioreactor chamber and said second chamber.
17. The bio-augmentation apparatus according to Claim 16, wherein said means for removing a predetermined supply of water, at least one of inorganic nutrients and organic nutrients, and microorganisms and means for delivering said removed predetermined supply of water, at least one of inorganic nutrients and organic nutrients and microorganisms into contact with an environment containing wastes to be biodegraded, includes a second pump operably connected in fluid communication between said bioreactor chamber and the environment containing wastes to be biodegraded.

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18. The bio-augmentation apparatus according to Claim 17, wherein said controller includes a timer and a regulator operably connected to said first pump and second pump to effectively maintain the microorganisms in substantially exponential growth in said bioreactor chamber.
19. A method for bio-augmenting the biodegradation of wastes, comprising the steps of:
 - a) providing a microorganism culture;
 - b) introducing a predetermined supply of water and at least one of inorganic nutrients and organic nutrients to said microorganism culture;
 - c) removing a predetermined supply of water, at least one of inorganic nutrients and organic nutrients, and microorganisms from said microorganism culture so that said microorganism culture is maintained in substantially exponential growth; and
 - d) delivering said removed predetermined supply of water, at least one of inorganic nutrients and organic nutrients and microorganisms into contact with an environment containing a waste for biodegrading the waste.
20. The method according to Claim 19, wherein said microorganisms culture includes at least one of anaerobic and aerobic microorganisms.
21. The method according to Claim 19, wherein said at least one of inorganic nutrients and organic nutrients are substantially similar to wastes contained in the waste to be biodegraded so as to acclimate the microorganisms to the waste to be biodegraded.

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22. The method according to Claim 19, wherein said microorganism culture is maintained in substantially exponential growth approximately midway between a lag phase growth and a stationary growth.
23. The method according to Claim 19, wherein said microorganism culture is maintained in a bioreactor chamber at a concentration of about 500 million cells/cubic centimeter to about 3 billion cells/cubic centimeter.
24. The method according to Claim 23, wherein said microorganism culture is maintained in a bioreactor chamber at a concentration of about 2.5 billion cells/cubic centimeter.
25. The method according to Claim 19, wherein said step of introducing a predetermined supply of water, at least one of inorganic nutrients and organic nutrients to said microorganisms culture is periodically performed.
26. The method according to Claim 25, wherein said step of removing a predetermined supply of water and at least one of inorganic nutrients and organic nutrients, and microorganisms from said microorganism culture is periodically performed so that said microorganism culture is maintained in substantially an exponential growth.
27. The method according to Claim 19, wherein said step of introducing a predetermined supply of water, at least one of inorganic nutrients and organic nutrients to said microorganisms culture is continuously performed.

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28. The method according to Claim 27, wherein said step of removing a predetermined supply of water, at least one of inorganic nutrients and organic nutrients, and microorganisms from said microorganism culture so that said microorganism culture is maintained in substantially an exponential growth is continuously performed.

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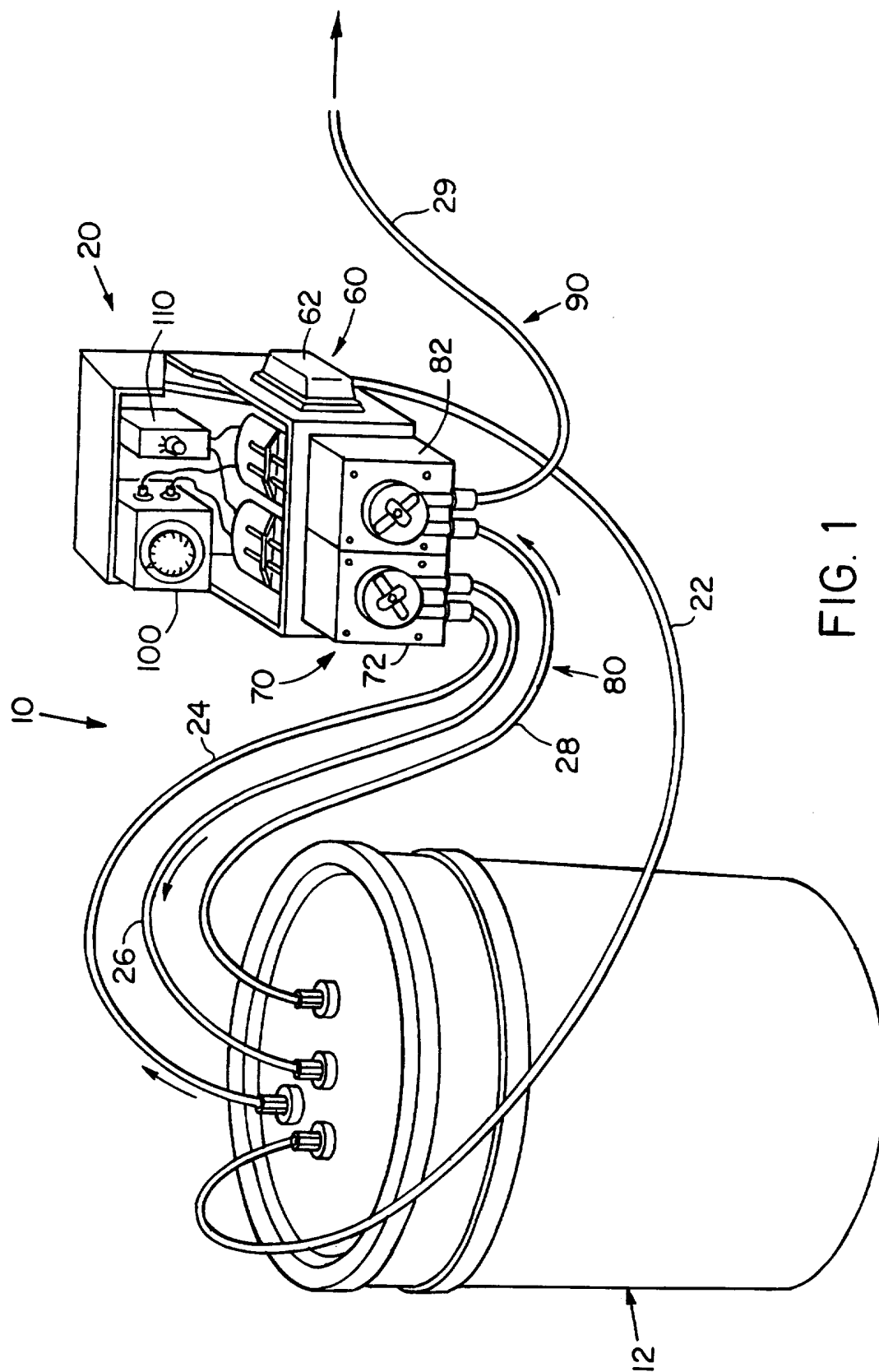


FIG. 1

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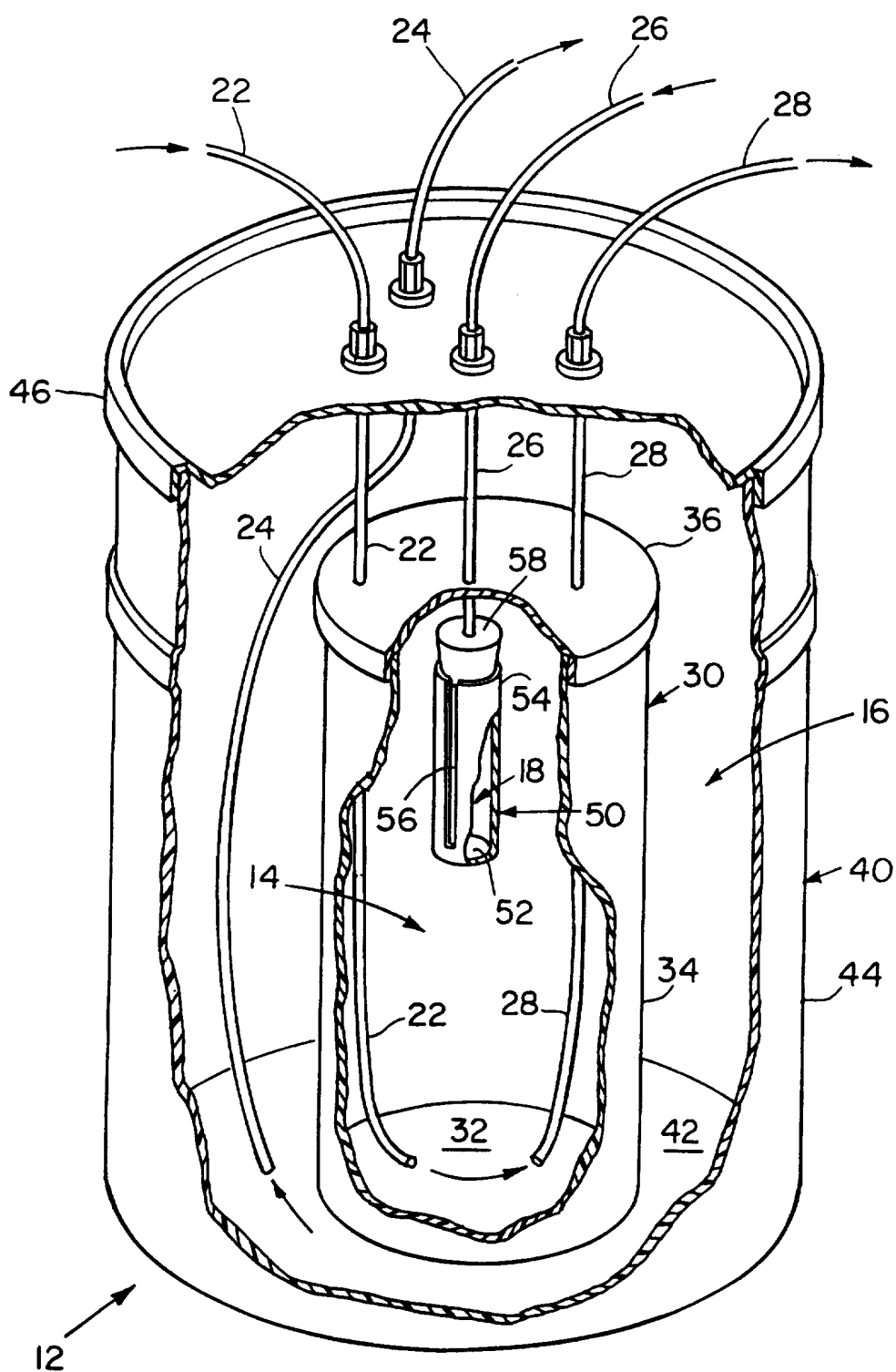


FIG. 2

SUBSTITUTE SHEET (RULE 26)

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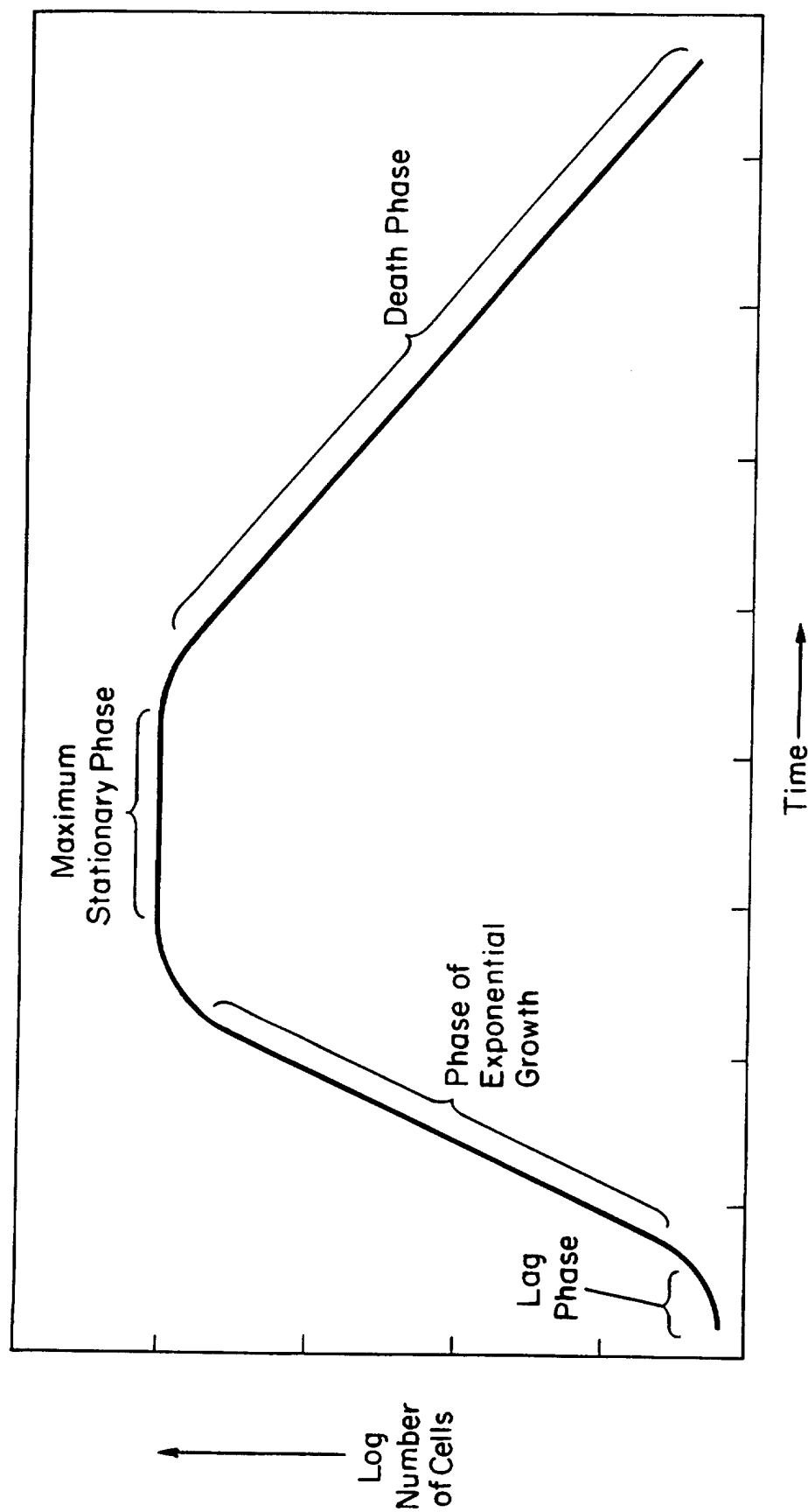


FIG. 3

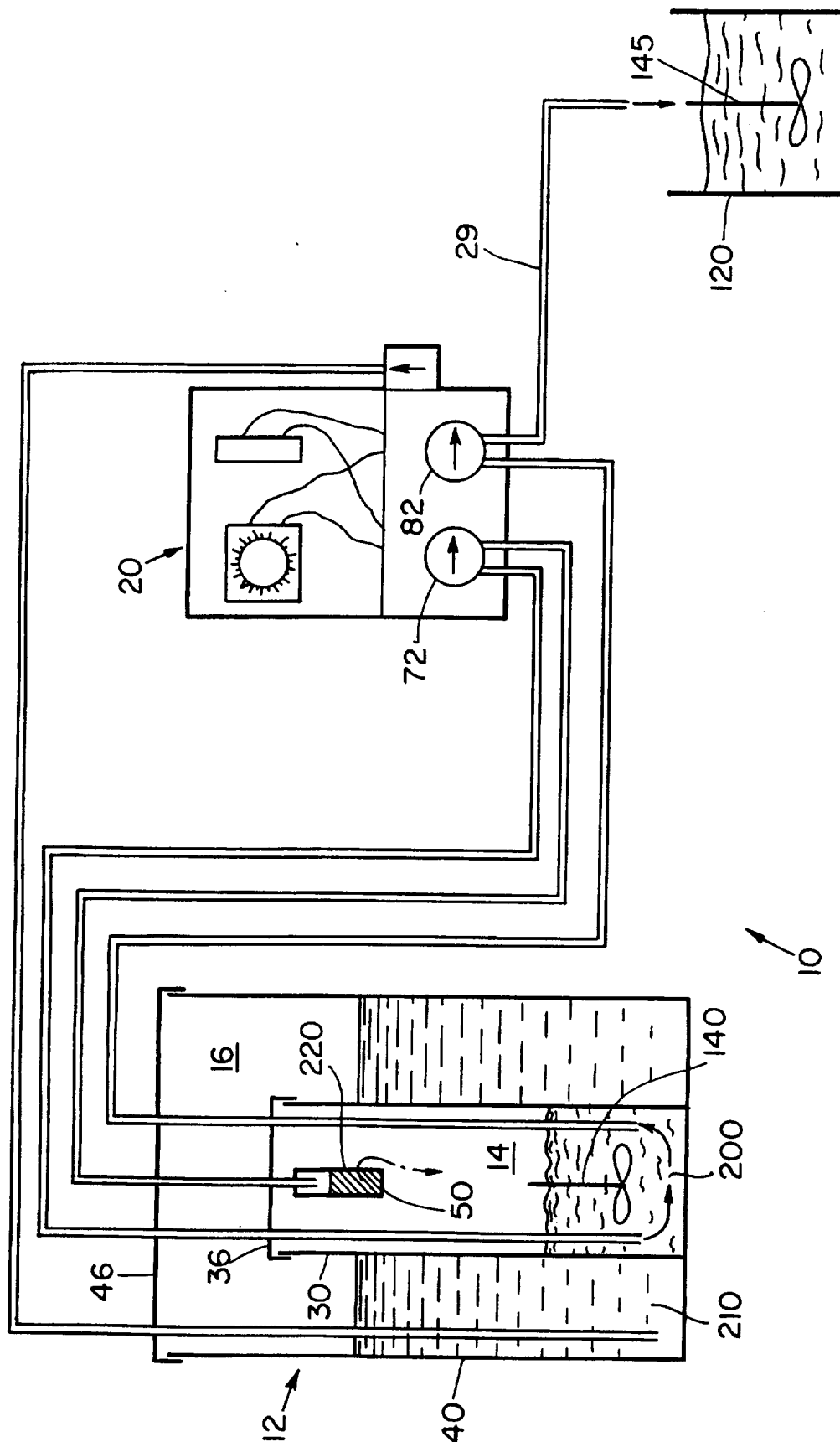


FIG. 4

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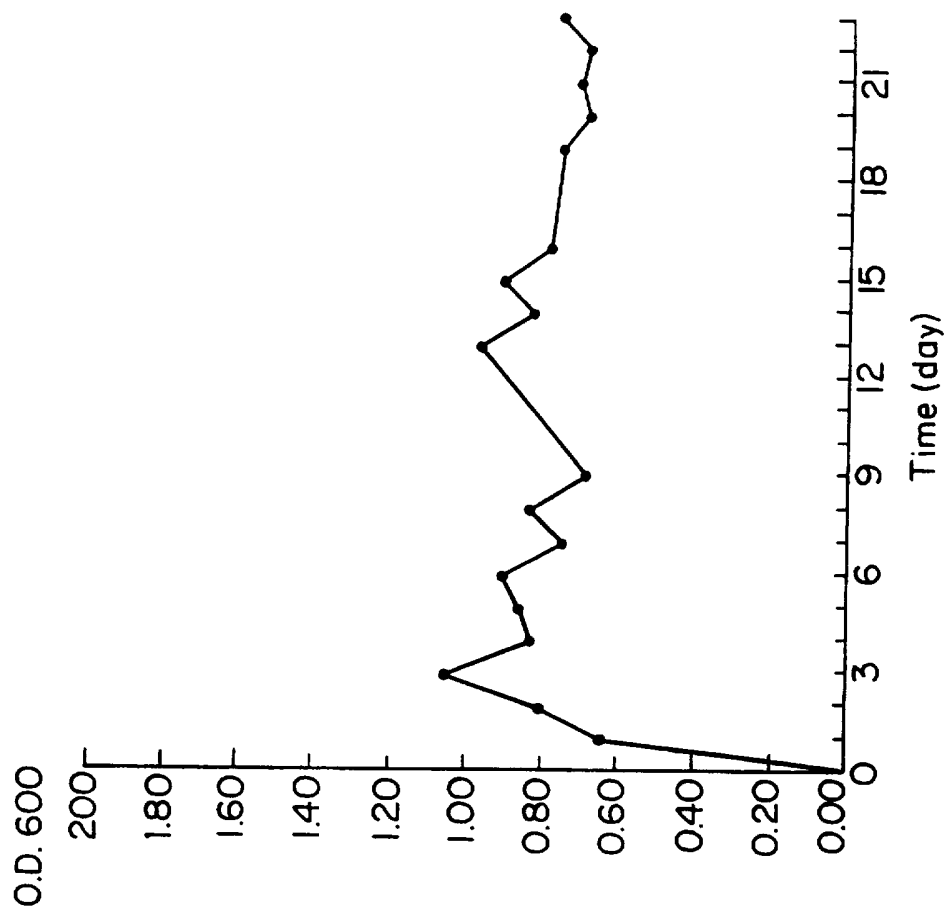


FIG. 5B

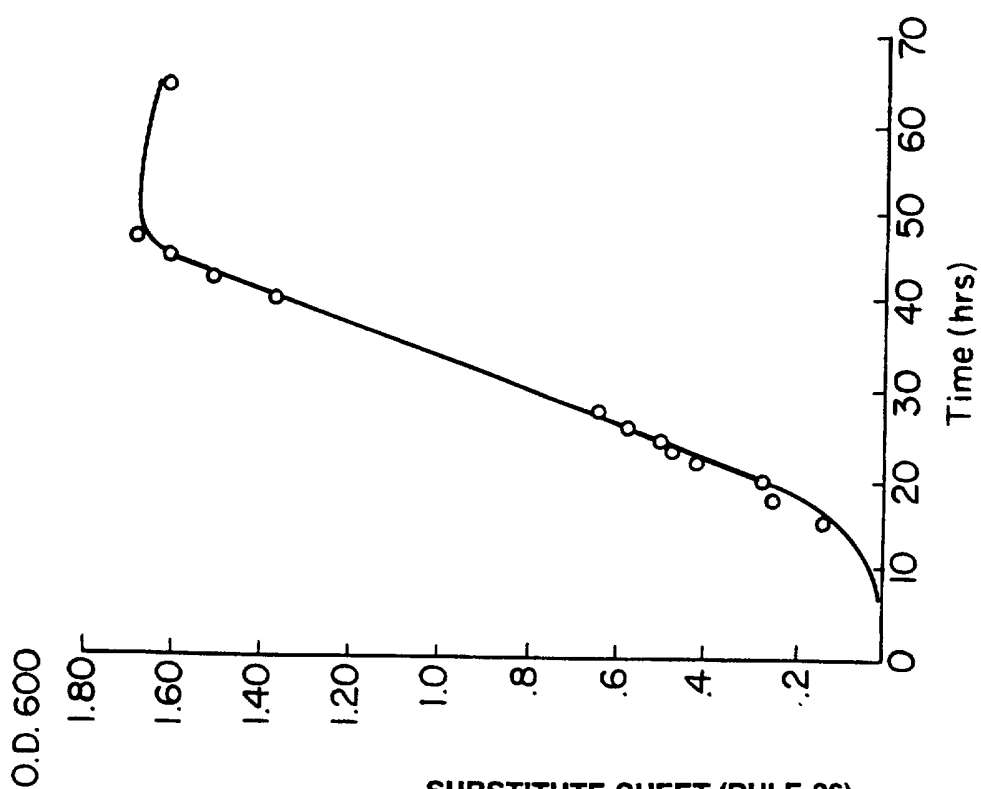


FIG. 5A

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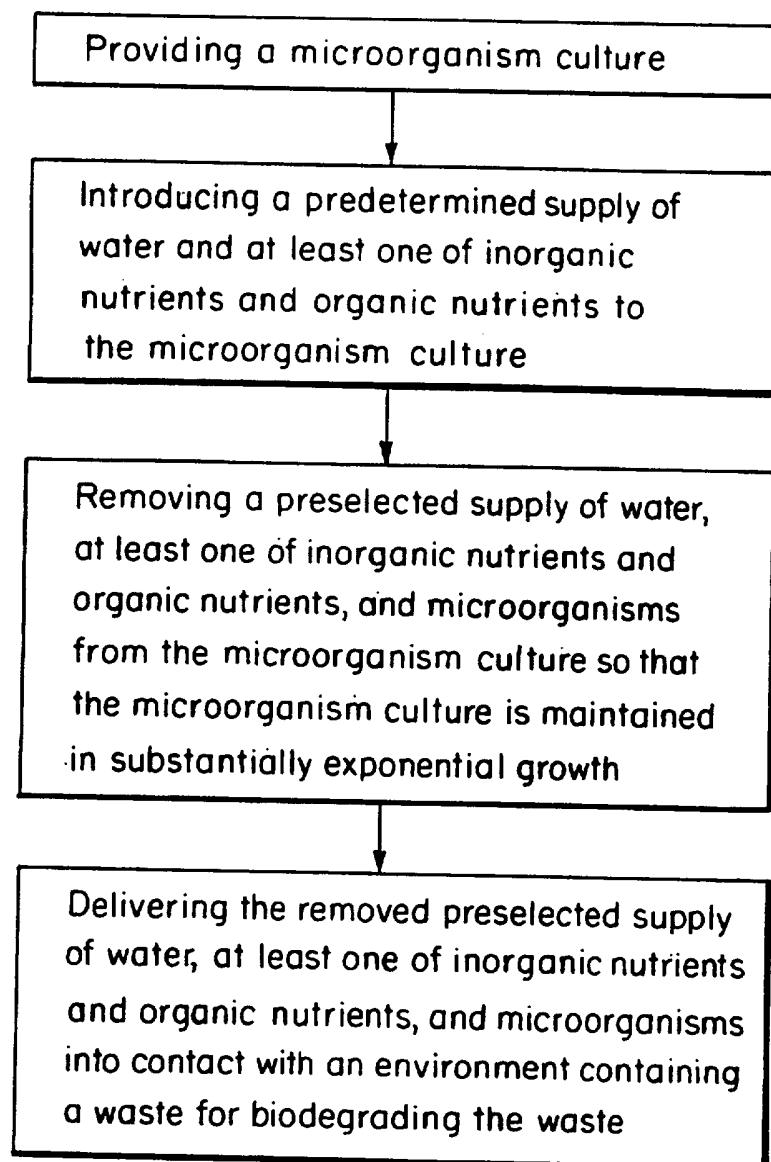


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/03672

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :C02F 3/00

US CL :210/606, 610, 620, 138, 202, 205; 435/262.5

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 210/606, 610, 611, 620, 631, 138, 202, 205, 209, 258, 259; 435/262, 262.5

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,227,068 A (RUNYON) 13 July 1993, see figure 1.	1-20, 22-26
Y	US 5,366,891 A (PREMUZIC et al) 22 November 1994, see figure 1.	1-20, 22-24, 27, 28
Y	US 4,992,174 A (CAPLAN et al) 12 February 1991, see figure 1.	1-24, 27, 28
X,P -- Y,P	US 5,531,898 A (WICKHAM) 02 July 1996, see column 7, lines 37-62.	1, 3-7, 19-21, 25, 26 ---- 8-18, 22-24

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	*T	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
A document defining the general state of the art which is not considered to be of particular relevance	*X*	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
E earlier document published on or after the international filing date	*Y*	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*G*	document member of the same patent family
O document referring to an oral disclosure, use, exhibition or other means		
P document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

07 MAY 1997

Date of mailing of the international search report

27 MAY 1997

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