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(54) **METHOD AND APPARATUS FOR TREATING WASTEWATER**

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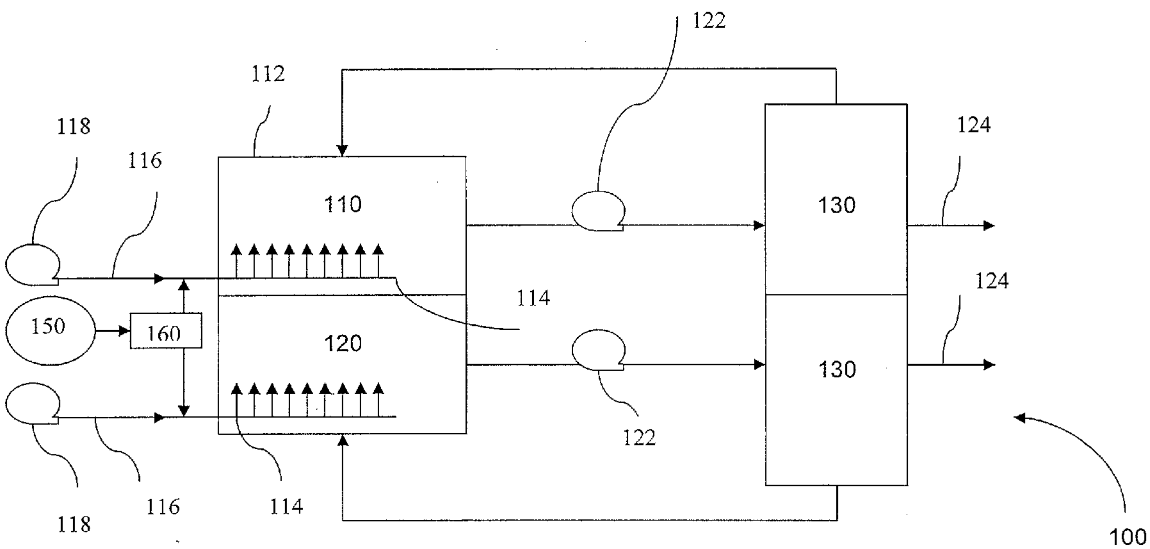
(57) **ABSTRACT**

The invention is directed to a method an apparatus for treating wastewater. The wastewater treatment system includes an aeration system that cycles between biological multiple biological basins. The system also includes one or more membrane basins. A method of the invention includes controlling the introduction of air into each biological basin in response to one or more operating conditions.



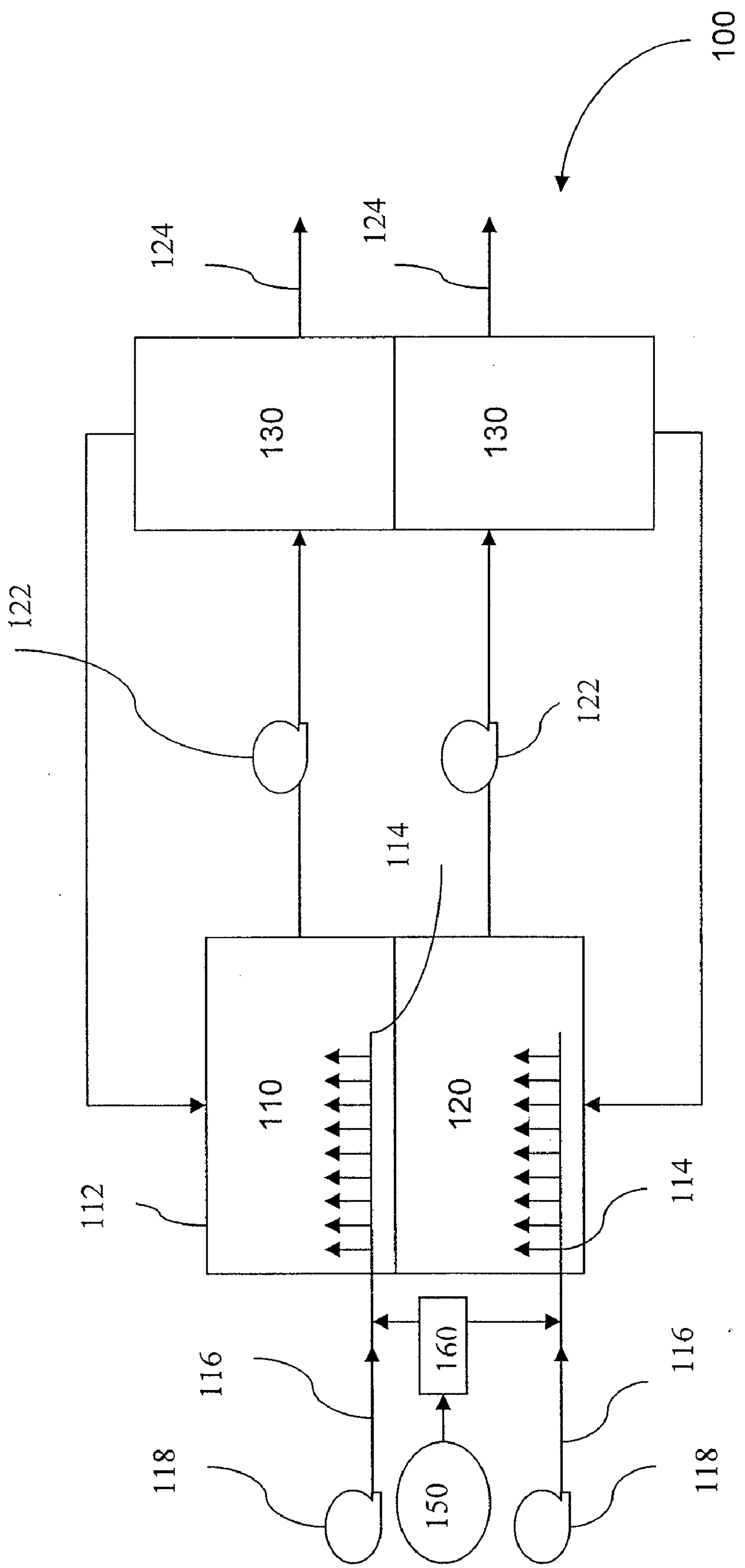

100
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FIG. 1

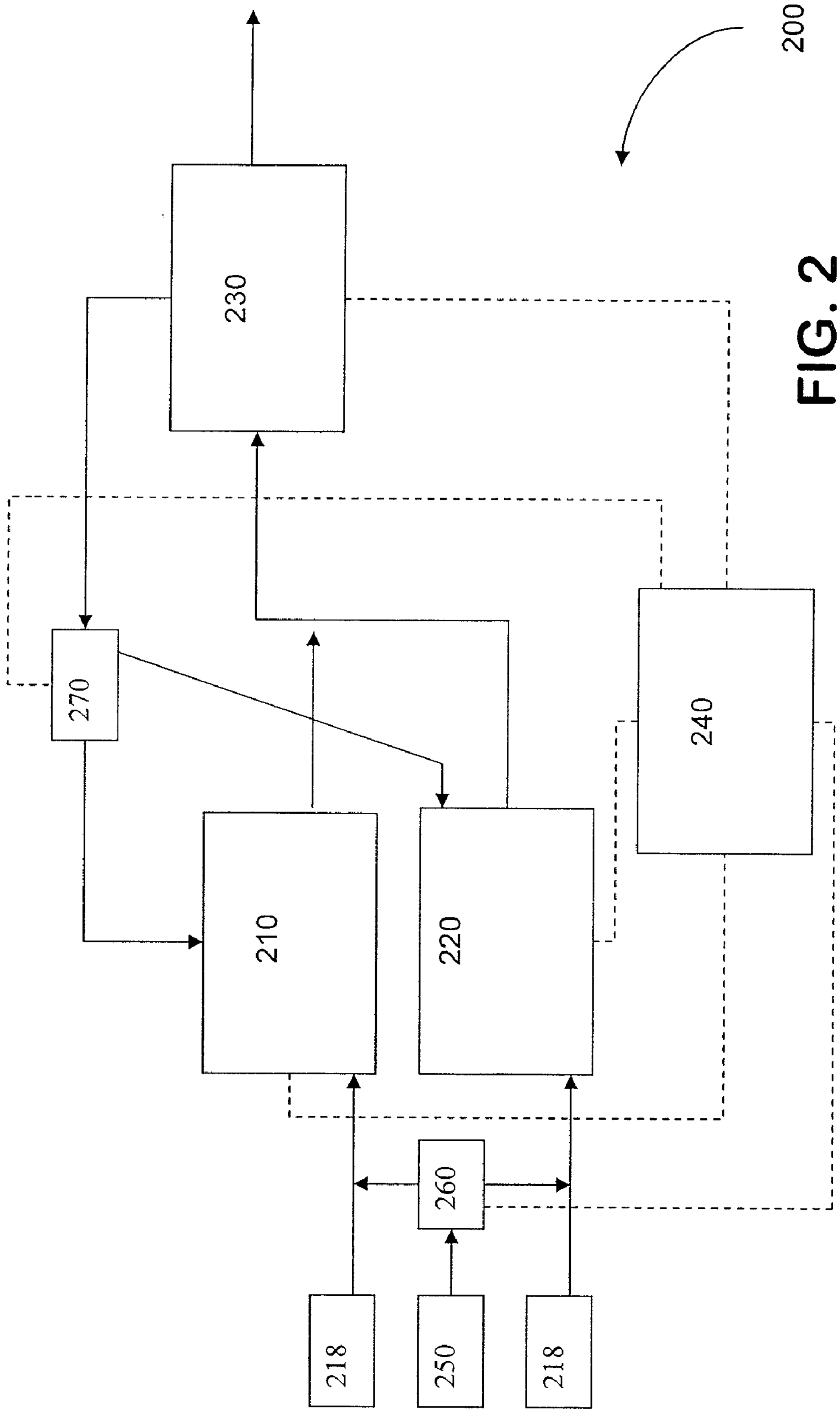

FIG. 2

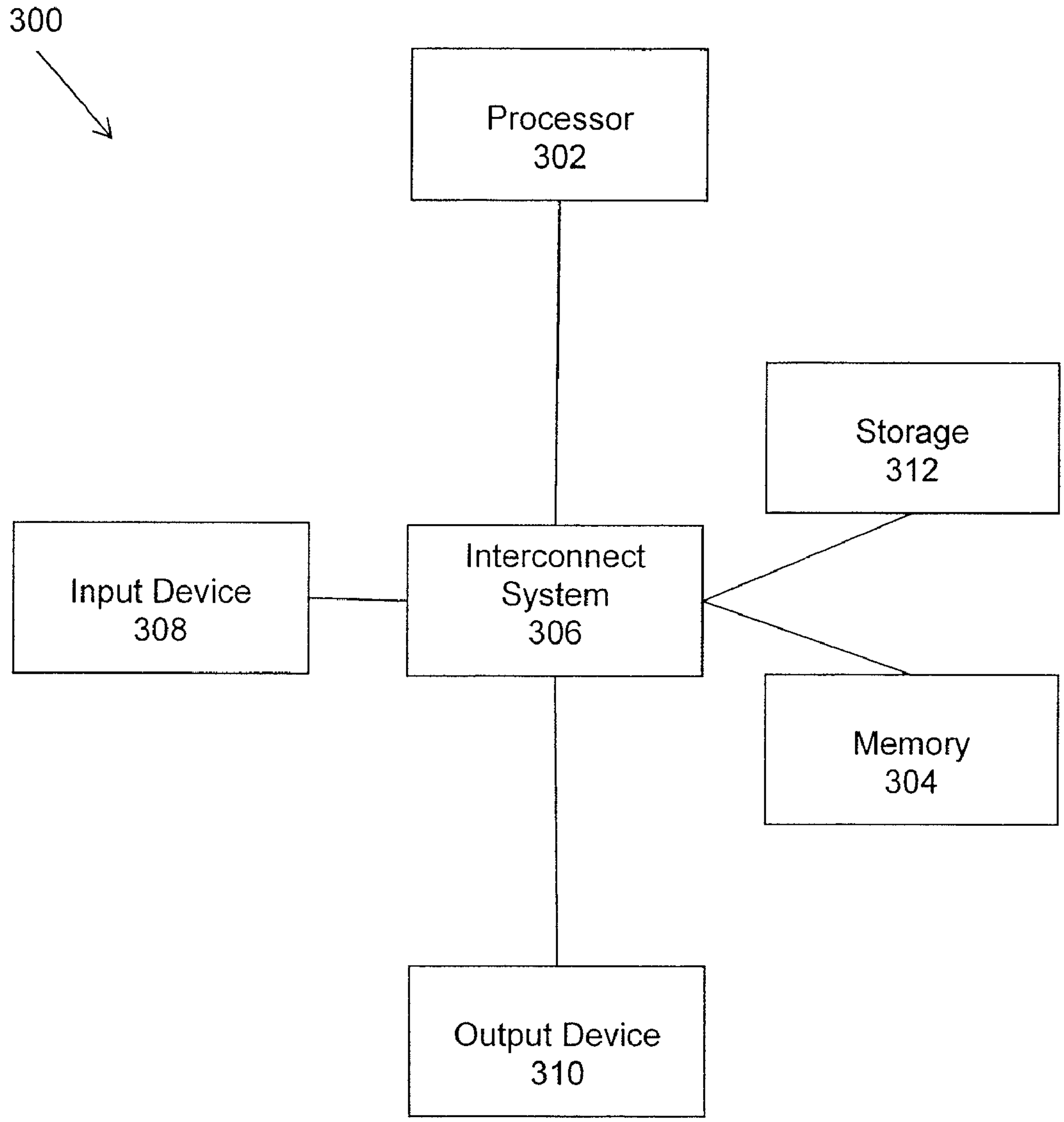
300
Processor
302
Storage
312
Input Device
308
Interconnect
System
306
Memory
304
Output Device
310

FIG. 3

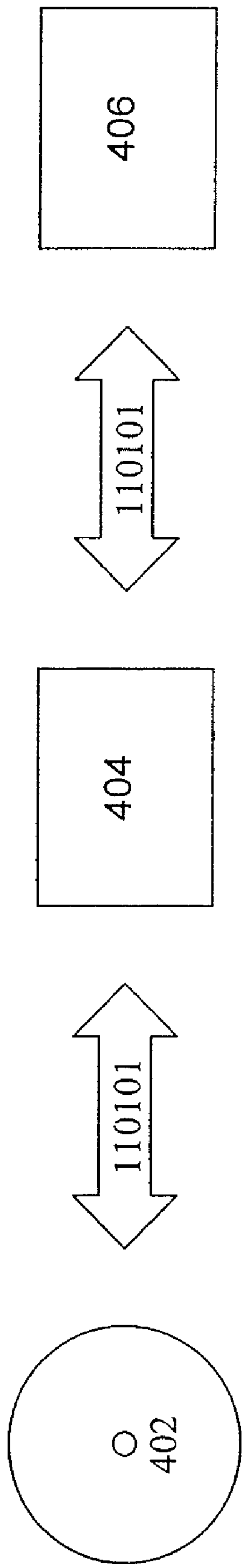

FIG. 4

METHOD AND APPARATUS FOR TREATING WASTEWATER

RELATED APPLICATIONS

[0001] This application claims priority under 35 U.S.C. § 119(e) to U.S. Provisional Application Ser. No. 60/723,745, entitled "METHOD AND APPARATUS FOR TREATING WASTEWATER," filed on Oct. 5, 2005, which is herein incorporated by reference in its entirety.

BACKGROUND OF INVENTION

[0002] 1. Field of Invention

[0003] The present invention relates to a system and method for treating wastewater, and more particularly to a wastewater treatment system and method utilizing a membrane bioreactor.

[0004] 2. Discussion of Related Art

[0005] The importance of membranes for treatment of waste water is growing rapidly. With the arrival of submerged membrane processes where the membrane modules are immersed in a large feed tank and filtrate is collected typically through suction applied to the filtrate side of the membrane, membrane bioreactors (MBRs) combining biological and physical processes in one stage promise to be more compact, efficient and economic. Membrane bioreactors are typically sized to accommodate community and large-scale sewage treatment, i.e. 160,000 gpd, and 20-40 mgd and more. However, construction and energy use costs associated with large scale MBR systems are significant.

SUMMARY OF INVENTION

[0006] In accordance with one or more embodiments, the invention relates to a system and method of treating wastewater.

[0007] In one embodiment, a wastewater treatment system includes a bioreactor comprising a first compartment and a second compartment, means for periodically aerating at least one of the first compartment and the second compartment, and a membrane bioreactor fluidly connected to at least one of an outlet of the first compartment and an outlet of the second compartment. In another embodiment, the means for aerating at least one compartment comprises a jet assembly positioned in each compartment.

[0008] Another embodiment is directed to a method or treating wastewater comprising providing a wastewater to one of a first compartment, a second compartment, and combinations thereof, alternating between anoxic conditions and aerobic conditions within the same compartment, and passing the wastewater from the at least one of the first compartment and the second compartment to a membrane bioreactor.

[0009] Another embodiment is directed to a computer-readable medium having computer-readable signals stored thereon that define instruction that, as a result of being executed by a computer, instruct the computer to perform a method of controlling a wastewater treatment system comprising actor of receiving an input signal respective of a characteristic of wastewater in a first compartment of a bioreactor and regulating an amount of air directed to the first compartment.

BRIEF DESCRIPTION OF DRAWINGS

[0010] The accompanying drawings, are not intended to be drawn to scale. In the drawings, each identical or nearly identical component that is illustrated in various figures is represented by a like numeral. For purposes of clarity, not every component may be labeled in every drawing. In the drawings:

[0011] FIG. **1** is a schematic diagram in accordance with one or more embodiments of the invention;

[0012] FIG. **2** is a block diagram illustrating a treatment system in accordance with one or more embodiments of the invention;

[0013] FIG. **3** is a schematic diagram illustrating a computer system upon which one or more embodiments of the invention may be practiced; and

[0014] FIG. **4** is a schematic illustration of a storage system that may be used with the computer system of FIG. **3** in accordance with one or more embodiment so the invention.

DETAILED DESCRIPTION

[0015] This invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments and of being practiced or of being carried out in various ways. Also, the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. The use of "including,""comprising," or "having,""containing,""involving," and variations thereof herein, is meant to encompass the items listed thereafter and equivalents thereof as well as additional items. Only the transitional phrases "consisting of" and "consisting essentially of" are closed or semi-closed transitional phrases, respectively, with respect to the claims. As used herein, the term "plurality" refers to two or more items or components.

[0016] The invention is directed to wastewater treatment systems utilizing membrane bioreactors (MBR's). "Wastewater," as used herein, defines a stream of waste from a residential or community source, having pollutants of biodegradable material, inorganic or organic compounds capable of being decomposed by bacteria, flowing into the wastewater treatment system. As used herein, a "wastewater treatment system" is a system, typically a biological treatment system, having a biomass population of bacterial micro-organisms of a diversity of types of bacteria, used to digest biodegradable material. Notably, the biomass requires an environment that provides the proper conditions for growth.

[0017] One embodiment of the present invention includes a plurality of biological basins operated simultaneously. The plurality of biological basins may comprise individual basins positioned near or adjacent to one another, or a single basin with a plurality of compartments. As used herein, the terms "basin" and "compartment" are used interchangeably to denote an individual treatment zone. In one embodiment, at least two basins are positioned adjacent one another and share a common interior wall which may reduce construction costs.

[0018] According to one embodiment, a suspension system may be disposed in each of the plurality of basins. The suspension system may be any system sufficient to suspend solids in the wastewater within the basin. For example, the suspension system may be a stirrer or a plurality of fluid jet streams. In one embodiment, the suspension system includes a plurality of jets positioned at or near a floor of each basin for delivering a jet stream of fluid and/or air.

[0019] In one embodiment, an aeration system is disposed in each of the plurality of basins. The aeration system may be any aeration system sufficient to deliver a suitable amount of air to promote aerobic conditions within the basin. The aeration system my produce fine bubbles, coarse bubbles, a jet stream of gas, and combinations thereof. The aeration system may be positioned in any suitable location within the compartment. In one embodiment, the aeration system is fluidly connected to the jet suspension system, that is to say, the aeration system and the fluidization system may be combined into one system. In one embodiment, when it is desirable to aerate one or more basins, air may be added to the wastewater in the fluidization system for delivery through a jet assembly. In one embodiment, a single source of air may be used to supply one or more aerations systems. For example, a single air blower may cycle air between and among multiple basins through switchover devices, such as diversion valves. The use of a single source of air to cycle aeration between two or more basins may reduce original equipment costs, which typically include an individual source of air for each basin.

[0020] In one embodiment, a common wastewater feed is fluidly connected to each jet suspension system in multiple basins. The jet suspension system operates continually in each basin fluidizing each basin. Air may then be cycled among the basins through the jet suspension system. When aeration of one or more basins is desired, air may diverted to one or more particular jet suspension systems of a particular basin or basins. When anoxic conditions are desired, a flow of air may be completely interrupted and air may be diverted away from the particular basin or basins. It is appreciated that the flow of air need not be completely interrupted when operating under anoxic conditions. For example, a minimum amount of air may be desired to assist in the anoxic process, so long as the air present under anoxic conditions is not sufficient to support aerobic conditions in the basin.

[0021] In one embodiment, a single blower may be used to cycle air among respective basins, wherein at any give time, one or more basins may run under aerobic conditions, while the remaining basin or basins may run under anoxic conditions. One advantage of the combined suspension/aeration system may a reduced incidence of clogging by settling solids as fluid (either wastewater or combined wastewater and air) is always passing through the combined suspension/aeration system.

[0022] The combined suspension/aeration system may have any configuration to provide adequate suspension and aeration for the desired application and treatment volume. For example, the combined system may comprise a jet assembly having a high efficiency jet having an orifice of a particular configuration and cross sectional area to promote suspension and aeration.

[0023] Switchover of air flow form one or more basins to another or multiple other basins may by manual or automatic, based upon time of operating conditions within the basins, sensors detecting a characteristic of the wastewater within the basins, or combinations thereof. For example, one or more sensors may detect dissolved oxygen content, oxidation reduction potential (ORP), alkalinity, and/or nitrate content of wastewater within a basin, thereby generating a signal indicating operating conditions are appropriate for either adding air or interrupting air flowing to a particular basin. In one embodiment, alternating between anoxic and aerobic conditions is based upon a duration of a particular cycle and a concentration of dissolved oxygen in the basin. In another embodiment, a decrease in the rate of change of the oxidation reduction potential may signal the end of the anoxic cycle.

[0024] Cycling between anoxic and aerobic conditions within the same basin may provide advantages over batch or sequential batch operations which require transfer of basin contents from one basin to another. For example, one advantage of cycling air among basins is that the contents of the basins need not be transferred to another basin in order to switch between anoxic and aerobic conditions, thereby reducing the number of basins required. The continuous operation of a single blower to supply at least two basins may also reduce energy costs.

[0025] One or more of the basins may be operated as a batch flow mode, a sequencing batch reactor, or as a continuous flow batch reactor having continuous wastewater inflow. In a continuous flow batch reactor, the wastewater may be directed to one or more basins equally, or directed to a particular basin based upon volume of flow or one or more physical or chemical characteristics of the wastewater. For example, the chemical makeup of incoming wastewater may determine whether the incoming wastewater is to be directed to a basin currently operating under anoxic conditions, or to a basin currently operating under aerobic conditions.

[0026] Because each basin cycles between anoxic and aerobic conditions, the residence time of wastewater within each basin determines the number of anoxic cycles and aerobic cycles to which the wastewater is exposed. For example, wastewater entering a basin may be exposed to to only one anoxic cycle and one aerobic cycle. However, under a longer residence time, wastewater entering a basin may be exposed to multiple anoxic and aerobic cycles.

[0027] The bacteria used in the basins may be any bacteria suitable to thrive in anoxic and/or anaerobic conditions. In one embodiment, the anoxic process may form facultative bacteria that may work in both anoxic and aerobic conditions.

[0028] In another embodiment, the effluent from one or more of the basins may be directed to one or more membrane basins, each membrane basin having one or more filter membranes positioned therein. The one or more membrane basins may be formed similar to the biological basins. For example, if multiple membrane basins are desired, the membrane basins may comprise individual basins positioned near or adjacent to one another, or a single basin with a plurality of compartments, sharing at least one interior wall. In one embodiment, the one or more biological basins are fluidly connected to one membrane basin. In another embodiment, at least two basins are fluidly connected to at least two membrane basins.

[0029] The filter membranes may have any configuration suitable for a particular purpose, such as sheet or hollow tube. The membrane may be formed of any material (natural or synthetic) suitable for a particular filtration. In one embodiment, the membrane is formed of polymeric hollow fibers. The one or more filter membranes may be positioned in one or more membrane modules. The membrane modules may have any shape and cross sectional area suitable for use in a desired application, for example, square, rectangular, or cylindrical. In one embodiment, the membrane modules are cylindrical.

[0030] According to one embodiment of the invention, one or more membrane modules may be positioned in a basin in such a way as to be completely submerged by fluid during operation. For example, the membrane module may be positioned horizontally, vertically, or at an angle within the basin. Multiple membrane modules may be positioned adjacent one another, or located at predetermined positions within the basin and may, but need not, be positioned in the same plane as others or parallel to one another. The membrane modules may be mounted directly to the basin or mounted to a module support which may be removably attached to the basin. In one embodiment, a plurality of membrane modules are mounted to a module support to facilitate membrane maintenance and/or replacement.

[0031] As exemplarily illustrated in FIG. **1**, some treatment systems **100** of the invention may comprise a biological basin **112** comprising two compartments **110**, **120**. Jet assembly systems **114** are fluidly connected to wastewater inlets **116** and aeration blower **150**. Jet pumps **118** operate continuously to introduce wastewater into compartments **110**, **120** as well as to suspend solids present in the wastewater. Aeration blower **150** also operates continuously providing a source of air that is cycled between the jet assembly **114** in compartment **110** and the jet assembly **114** in compartment **120**. A switchover device **160** directs the flow of air between the two jet assemblies. Compartment **110** is fluidly connected to a first membrane basin **130**. Compartment **120** is fluidly connected to a second membrane basin **130**. Pumps **122** direct treated wastewater from each compartment **110**, **120** to membrane basins **130**, and assist in recycling missed liquor from the first and second membrane basins **130** to compartment **110** and compartment **120**, respectively. Filtrate exits membrane basins **130** through lines **124**.

[0032] During operation, switchover device **160** diverts air to compartment **110** and interrupts air flow to compartment **120** so that compartment **110** operates under aerobic conditions and compartment **120** operates under anoxic conditions. Switchover device **160** may then interrupt air to the jet assembly **114** in compartment **110**, and direct air to the jet assembly **114** in compartment **120**, at which time conditions in compartment **110** change from aerobic to anoxic, and conditions in compartment **120** change from anoxic to aerobic.

[0033] Some aspects of the invention may be particularly directed to controlling waste treatment operations that utilize membrane filtration techniques. For example, with reference to FIG. **2**, a wastewater treatment system **200** may comprise a first biological compartment **210**, a second biological compartment **220** and a membrane compartment **230**. Facultative bacteria, which functions in both anoxic and aerobic conditions, may be positioned in both compartments **210**, **220**. Wastewater enters compartments **210**, **220** from wastewater source **218**, such as jet pumps. A source of air **250**, such as a blower, delivers air to one or both compartments **210**, **220** through switchover device **260**. Concentrated mixed liquor may be directed from membrane compartment **230** to one or both of compartments **210**, **220** via switchover device **270**.

[0034] Controller **240** may respond to signals from sensors (not shown) positioned at any particular location within the system. For example, a sensor in compartment **210**, which may be operating under anoxic conditions, may generate a signal indicating that denitrification has reached a desired extent of completion. Controller **240** may respond by generating a control signal causing switchover device **260** to direct air to compartment **210**. Similarly, a sensor (not shown) in compartment **220**, which may be operating under aerobic conditions, may generate a signal indicating that oxidation has reached a desired extent of completion. Controller **240** may respond by generating a control signal causing switchover device **260** to interrupt flow of air to compartment **220**.

[0035] Controller **240** may also respond to one or more sensors positioned in membrane compartment **230**. For example, a sensor in membrane compartment **230** may generate a signal indicating the concentrated mixed liquor being recycled from membrane compartment **230** should be further exposed to anoxic conditions. Controller **240** may respond by generating a control signal to switchover device **270** to direct recycled concentrated mixed liquor to either or both compartments **210**, **220** which may be operating under anoxic conditions. Similarly, controller **240** may respond to one or more sensors (not shown) positioned in a wastewater inlet to generate a signal to a flow controller (not shown) to direct incoming wastewater to one or both compartments **210**, **220**.

[0036] The system and controller of one or more embodiments of the invention provide a versatile unit having multiple modes of operation, which can respond to multiple inputs to increase the efficiency of the wastewater treatment system.

[0037] The controller of the system of the invention **240** may be implemented using one or more computer systems **300** as exemplarily shown in FIG. **3**. Computer system **300** may be, for example, a general-purpose computer such as those based on in Intel PENTIUM®-type processor, a Motorol PowerPC® processor, a Hewlett-Packard PA-RISC® processor, a Sun UltraAPARC® processor, or any other type of processor or combination thereof. Alternatively, the computer system may include specially-programmed, special-purpose hardware, for example, an application-specific integrated circuit (ASIC) or controllers intended for water treatment systems.

[0038] Computer system **300** can include one or more processors **302** typically connected to one or more memory devices **304**, which can comprise, for example, any one or more of a disk drive memory, a flash memory device, a RAM memory device, or other device for storing data. Memory **304** is typically used for storing programs and data during operation of the system **200** and/or computer system **300**. For example, memory **304** may be used for storing historical data relating to the parameters over a period of time, as well as operating data. Software, including programming code that implements embodiments of the invention, can be stored on a computer readable and/or writeable nonvolatile recording medium (discussed further with respect to FIG. **4**), and then typically copied into memory **304** wherein it can then be executed by processor **302**. Such programming code may be written in any of a plurality of programming languages, for example, Java, Visual Basic, C, C#, or C++, Fortran, Pascal, Eiffel, Basic, COBAL, or any of a variety of combinations thereof.

[0039] Components of computer system **300** may be coupled by one or more interconnection mechanisms **306**, which may include one or more busses (e.g., between components that are integrated within a same device) and/or a network (e.g., between components that reside on separate discrete devices). The interconnection mechanism typically enables communications (e.g., data, instructions) to be exchanged between components of system **300**.

[0040] Computer system **300** can also include one or more input devices **308**, for example, a keyboard, mouse, trackball, microphone, touch screen, and other man-machine interface devices as well as one or more output devices **310**, for example, a printing device, display screen, or speaker. In addition, computer system **300** may contain one or more interfaces (not shown) that can connect computer system **300** to a communication network (in addition or as an alternative to the network that may be formed by one or more of the components of system **300**).

[0041] According to one or more embodiments of the invention, the one or more input devices **308** may include sensors for measuring parameters of system **200** and/or components thereof. Alternatively, the sensors, the metering valves and/or pumps, or all of these components may be connected to a communication network (not shown) that is operatively coupled to computer system **300**. For example, one or more compartments **210**, **220**, and **230**, and/or components thereof, may be configured as input devices that are connected to computer system **300**. Any one or more of the above may be coupled to another computer system or component to communicate with computer system **300** over one or more communication networks. Such a configuration permits any sensor or signal-generating device to be located at a significant distance from the computer system and/or allow any sensor to be located at a significant distance from any subsystem and/or the controller, while still providing data therebetween. Such communication mechanisms may be effected by utilizing any suitable technique including but not limited to those utilizing wireless protocols.

[0042] As exemplarily shown in FIG. **4**, controller **300** can include one or more computer storage media such as readable and/or writeable nonvolatile recording medium **402** in which signals can be stored that define a program to be executed by one or more processors **302**. Medium **402** may, for example, be a disk or flash memory. In typical operation, processor **302** can cause data, such as code that implements one or more embodiments of the invention, to be read from storage medium **402** into a memory **404** that allows for faster access to the information by the one or more processors than does medium **402**. Memory **404** is typically a volatile, random access memory such as a dynamic random access memory (DRAM) or static memory (SRAM) or other suitable devices that facilitates information transfer to and from processor **302**.

[0043] Although computer system **300** is shown by way of example as one type of computer system upon which various aspects of the invention may be practiced, it should be appreciated that the invention is not limited to being implemented in software, or on the computer system as exemplarily shown. Indeed, rather than implemented on, for example, a general purpose computer system, the controller, or components or subsections thereof, may alternatively be implemented as a dedicated system or as a dedicated programmable logic controller (PLC) or in a distributed control system. Further, it should be appreciated that one or more features or aspects of the invention may be implemented in software, hardware or firmware, or any combination thereof. For example, one or more segments of an algorithm executable by controller **240** can be performed in separate computers, which in turn, can be communication through one or more networks.

[0044] Having thus described several aspects of at least one embodiment of this invention, it should be apparent to those skilled in the art that the foregoing is merely illustrative and not limiting, having been presented by way of example only. Numerous modification and other embodiments are within the scope of the invention. In particular, although many embodiments presented herein involve specific combinations of method acts or system elements, it should be understood that those acts and those elements may be combined in other ways to accomplish the same objectives.

[0045] Further, acts, elements, and features discusses only in connection with one embodiment are not intended to be excluded from a similar role in other embodiments.

[0046] It is to be appreciated that various alterations, modifications, and improvements can readily occur to those skilled in the art ant that such alterations, modifications, and improvements are intended to be part of the disclosure and within the spirit and scope of the invention.

[0047] Moreover, it should also be appreciated that the invention is directed to each feature, system, subsystem, or technique described herein and any combination of two or more features, systems, subsystems, and/or method, if such features, systems, subsystems, and techniques are not mutually inconsistent, is considered to be within the scope of the invention as embodied in the claims.

[0048] Use of ordinal terms such as "first,""second, ""third," and the like in the claims to modify a claim element does not by itself connote any priority, precedence, or order of one claimed element over another or the temporal order in which acts of a method are performed, but are used merely as labels to distinguish one claim element having a certain name from another element having a same name (but for use of the ordinal term) to distinguish the claim elements.

[0049] Those skilled in the art should appreciate that the parameters and configuration described herein are exemplary and that actual parameters and/or configurations will depend on the specific application in which the systems and techniques of the invention are used. Those skilled in the art should also recognize or be able to ascertain, using no more than routing experimentation, equivalents to the specific embodiments of the invention. It is therefore to be understood that the embodiments described herein are presented by way of example only and that, within the scope of the appended claims and equivalents thereto; the invention my be practice otherwise than as specifically described.

What is claimed is:

1-21. (canceled)

22. A process of nitrifying and denitrifying wastewater and reducing or minimizing the DO concentration in a denitrification zone of a nitrification/denitrification system that includes an aerobic reactor having one or more immersed membranes contained therein comprising:

alternatively directing a wastewater influent into first and second zones;

at various times during the process maintaining the first zone as a nitrification zone and maintaining the second zone as a denitrification zone, and at various other times, maintaining the first zone at a denitrification zone and the second zone as a nitrification zone;

directing wastewater from either of the first or second zones to the downstream aerobic reactor having the one or more immersed membranes therein;

aerating the aerobic reactor;

directing wastewater in the aerobic reactor into the one or more immersed membranes and separating the wastewater into a permeate and return activated sludge;

pumping the permeate from the one or more immersed membranes in the aerobic reactor;

returning activated sludge from the aerobic reactor to either of the first or second zones; and

during the process reducing or minimizing the DO concentration in the denitrification zones by selectively directing the return activated sludge to one of the first or second zones being maintained as a nitrification zone and switching the flow of the return activated sludge during the process between the first and second zones so as to direct the return activated sludge to the first or second zone being maintained as the nitrification zone.

23. The process of claim 22, wherein the wastewater flow from the first and second zones to the downstream aerobic reactor is switched such that the flow of wastewater to the downstream aerobic reactor is from the zone being maintained as a nitrification zone.

24. The process of claim 23, wherein at various times both the first and second zones are maintained as nitrification zones.

25. The process of claim 22, wherein at various times one of the first or second zones is maintained as a denitrification zone and the other zone is maintained as a nitrification zone.

26. A process of nitrifying and denitrifying wastewater utilizing first and second reactors and a downstream third aerobic reactor having one or more immersed membrane filters contained therein, the process comprising:

alternatively directing influent wastewater into the first and second reactors;

alternatively nitrifying and denitrifying the wastewater in the first and second reactors such that at one time the first reactor performs a nitrification function while the second reactor performs a denitrification function, and at another time the first reactor performs a denitrifying function while the second reactor performs a nitrifying function;

alternatively directing influent from the first and second reactors to the downstream third aerobic reactor having the one or more immersed membrane filters contained therein;

filtering the wastewater in the downstream third aerobic reactor by directing the wastewater into the immersed membrane filter and separating the wastewater into filtered effluent and activated sludge;

pumping the filtered effluent from the immersed membrane filter; and

returning activated sludge from the downstream third aerobic reactor having the immersed membrane filtered therein to one of the first or second reactors functioning to nitrify the wastewater.

27. The process of claim 26, wherein during the process of treating the wastewater each of the first and second reactors switch between nitrifying and denitrifying the wastewater; and wherein there is provided a return activated sludge line between the downstream third aerobic reactor and each of the first and second reactors, and wherein the flow of return activated sludge is switched between the two return activated sludge lines such that return activated sludge is recycled to the first or second reactor nitrifying the wastewater.

* * * * *