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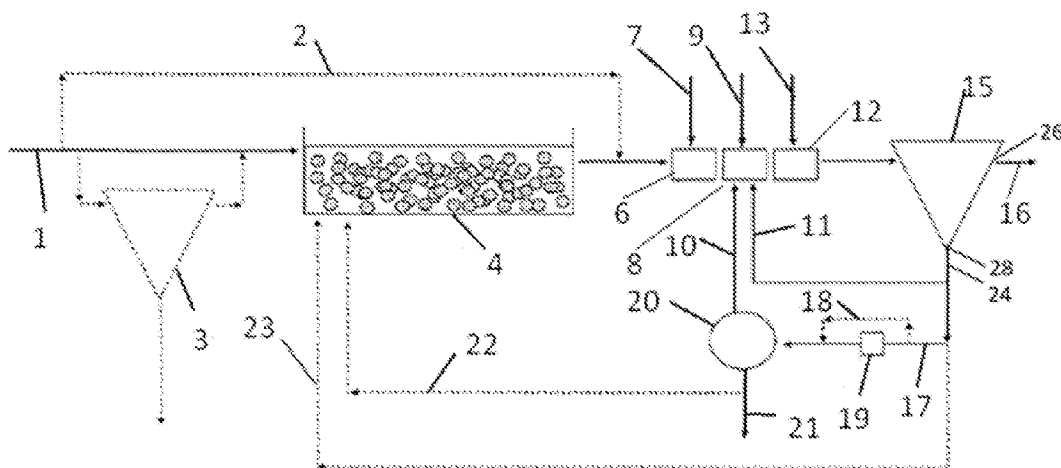
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(57) **Abrégé/Abstract:**

A system and method is provided for water and wastewater treatment. The system comprises a fixed film biological process and a ballasted flocculation process. The system comprises a fixed film reactor fluidly connected to a source of wastewater and configured to provide a fixed film effluent. The system further comprises a source of ballast fluidly connected to the fixed film effluent and configured to provide a ballasted effluent. A clarifier is provided in the system that is fluidly connected to the ballasted effluent. The clarifier comprises a treated effluent outlet and a ballasted solids outlet and is configured to separate a treated diluent from ballasted solids.

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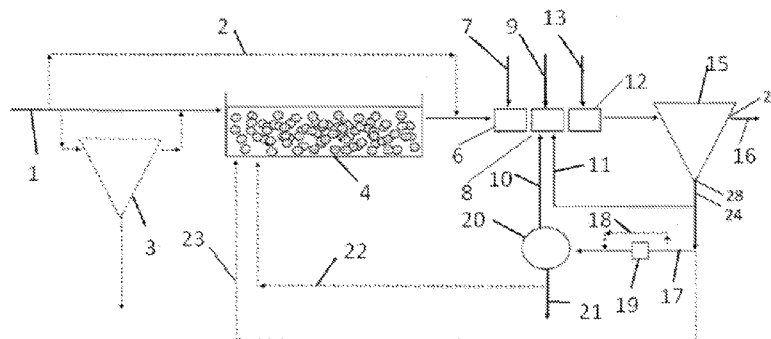


FIG. 1

(57) Abstract: A system and method is provided for water and wastewater treatment. The system comprises a fixed film biological process and a ballasted flocculation process. The system comprises a fixed film reactor fluidly connected to a source of wastewater and configured to provide a fixed film effluent. The system further comprises a source of ballast fluidly connected to the fixed film effluent and configured to provide a ballasted effluent. A clarifier is provided in the system that is fluidly connected to the ballasted effluent. The clarifier comprises a treated effluent outlet and a ballasted solids outlet and is configured to separate a treated diluent from ballasted solids.

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TREATMENT USING FIXED FILM PROCESSES AND BALLASTED SETTLING

FIELD OF TECHNOLOGY

One or more aspects of the disclosure relate generally to water and wastewater
5 treatment, and more particularly to systems and methods for water and wastewater treatment
using fixed film processes and ballasted settling.

SUMMARY

A system for treating wastewater is provided. The system comprises a fixed film
10 reactor fluidly connected to a source of wastewater and configured to provide a fixed film
effluent. The system further comprises a source of ballast fluidly connected to the fixed film
effluent and configured to provide a ballasted effluent. A clarifier is provided in the system
that is fluidly connected to the ballasted effluent. The clarifier comprises a treated effluent
outlet and a ballasted solids outlet and is configured to separate a treated effluent from a
15 ballasted solids.

A method for treating a wastewater is also provided. The method comprises
introducing a source of wastewater to a fixed film reactor to provide a fixed film effluent.
The method further comprises adding a ballast to provide a ballasted effluent. The method
further comprises separating the ballasted effluent into a treated effluent and a ballasted
20 solids in a clarifier, and separating the ballasted solids into a recovered ballast and a ballast-
free solids. The method further comprises adding the recovered ballast to the coagulated
effluent.

A method for retrofitting a wastewater treatment system is also provided. The
wastewater treatment comprises a fixed film bioreactor and a clarifier positioned downstream
25 of the fixed film bioreactor. The clarifier comprises a solids outlet. The method for
retrofitting comprises installing a coagulation tank in the clarifier, and installing a ballast feed
tank connected downstream of the coagulant tank in the clarifier. The method of retrofitting
further comprises connecting the solids outlet of the clarifier to the ballast feed tank.

In various embodiments, a system for treating wastewater is provided, comprising: a
30 fixed film reactor fluidly connected to a source of wastewater and configured to provide a
fixed film effluent, wherein the fixed film effluent comprises wastewater and biological
solids produced in the fixed film reactor; a source of coagulant fluidly connected to a
coagulant tank connected downstream of the fixed film reactor configured to provide a
coagulated effluent; a source of ballast fluidly connected to a ballast feed tank connected

downstream of the coagulant tank, wherein the ballast feed tank is configured to provide a ballasted effluent and the ballast comprises magnetite; and a clarifier fluidly connected to at least one of the ballast feed tank providing the ballasted effluent, the coagulant tank providing coagulated effluent, and the fixed film reactor, the clarifier comprising a treated effluent outlet and a ballasted solids outlet and configured to separate a treated effluent from ballasted solids.

In various embodiments, a method for treating a wastewater is provided, comprising: introducing wastewater from a source of wastewater to a fixed film reactor to provide a fixed film effluent, wherein the fixed film effluent comprises wastewater and biological solids produced in the fixed film reactor; adding a coagulant to the fixed film effluent to provide a coagulated effluent; following coagulation addition further adding a ballast in a ballast mixing step in a ballast feed tank downstream of the coagulant tank to provide a ballasted effluent, wherein the ballast comprises magnetite; introducing the ballasted effluent into a clarifier and separating the ballasted effluent into a treated effluent and ballasted solids in the clarifier; separating the ballasted solids into a recovered ballast and a ballast-free solids; and adding the recovered ballast to the coagulated effluent.

In various embodiments, a method for retrofitting a wastewater treatment system comprising a fixed film bioreactor and a clarifier positioned downstream of the fixed film bioreactor and comprising a solids outlet, the method comprising: installing a coagulation tank in the clarifier, wherein the coagulation tank is connected downstream of the fixed film reactor; installing a ballast feed tank connected downstream of the coagulant tank in the clarifier; wherein the ballast comprises magnetite; the clarifier fluidly connected to at least one of the ballast feed tank, the coagulant tank, and the fixed film reactor, and connecting the solids outlet of the clarifier to the ballast feed tank.

DESCRIPTION OF THE DRAWINGS

The accompanying drawings are not intended to be drawn to scale. For purposes of clarity, not every component may be labeled in the drawings, nor is every component of each embodiment of the disclosure shown where illustration is not necessary to allow those of ordinary skill in the art to understand the disclosure.

In the drawings:

FIG. 1 presents a schematic of a treatment system implementing a fixed film process, ballasted settling, and recovery of ballast in accordance with one or more embodiments of the disclosure; and

5 FIG. 2 presents a schematic of reaction tanks integrated into a clarifier tank in accordance with one or more embodiments of the disclosure.

DETAILED DESCRIPTION

Systems and methods are provided for treating water or wastewater. The systems and
10 methods may comprise treating a water or wastewater in a fixed film reactor, also referred to as a fixed film biological system or attached growth system. The systems and methods may further comprise treating the effluent from the fixed film biological system in a ballasted settling process, or a ballasted flocculation system.

A fixed film biological system may oxidize and reduce soluble substrate, eliminating
15 impurities and producing solids. Fixed film processes may maintain biological growth on a surface or inert carrier or sheet and the treated effluent from the fixed film bioreactor may contain about 50 milligrams per liter (mg/l) to about 300 mg/l of biological solids. In certain embodiments, the treated effluent may contain between about 100 mg/l to about 200 mg/l. In certain embodiments, the treated effluent from the fixed film bioreactor may contain about 50
20 mg/l to about 2,000 mg/l of biological solids. Examples of fixed film processes include, without limitation, moving bed bioreactors (MBBR's), trickling filters, and rotating biological contactors. Typically, wastewater is filtered through a primary or coarse screen and/or is treated in a primary clarification unit. Effluent of these primary processes or a raw wastewater may enter a fixed film biological system where soluble substrate is oxidized or
25 reduced to biological solids in the form of slough from the fixed biomass on the inert carrier or sheet of the fixed film reactor. Aeration may be supplied in aerobic zones to supply oxygen and mixing to the system. In anaerobic, anoxic, or aerated anoxic based systems, mixers or mixers with aeration may be provided to maintain mixing throughout.

The fixed film biological system may provide an effluent comprising biological
30 solids, often referred to as slough, which requires separation from a treated effluent in a downstream process. While fixed film processes have a small footprint, effluent biological solids from the process are often difficult to settle with conventional sedimentation processes frequently requiring a large settling area. Clarification, therefore, is often the limiting step in

the rate of wastewater treatment involving fixed film biological systems or fixed film reactors.

Ballasted flocculation systems or ballasted settling systems may comprise the addition of a coagulant, ballast, and, optionally, a flocculant to improve the removal of dissolved, colloidal, particulate and microbiological solids. In certain embodiments, the coagulant may be optional. For example, ballast and flocculant may be added, without coagulant. In other embodiments, ballast may be added without coagulant and flocculant. In other embodiments, ballast and coagulant may be added, without flocculant. The precipitation and enhanced settlability of ballasted solids provides for a small clarification step, which may allow for a small footprint system comprising biological and clarification steps. According to embodiments of the present disclosure, ballasted flocculation systems may eliminate the need to provide a secondary clarifier directly downstream of a fixed film biological system or reactor. Further, the ballasted flocculation system may be installed between the fixed film bioreactor and the secondary clarifier, thereby using the existing secondary clarifier as the ballasted flocculation clarifier and eliminating the need for a new clarifier.

Flocculation may be a process of contact and adhesion whereby particles and colloids in liquid such as a water or wastewater form larger-size clusters of material. Particles may cluster together into a floc. A flocculant may comprise a material or a chemical that promotes flocculation by causing colloids and particles or other suspended particles in liquids to aggregate, forming a floc. Polymer may be used as flocculants. For example, acrylic acid/acrylamide copolymers and modified polyacrylamides may be used.

Coagulation may be a process of consolidating particles, such as colloidal solids. Coagulants may include cations, such as multivalent cations. They may include cations such as aluminum, iron, calcium or magnesium (positively charged molecules) that may interact with negatively charged particles and molecules that reduce the barriers to aggregation. Examples of coagulants include bentonite clay, polyaluminum chloride, polyaluminum hydroxychloride, aluminum chloride, aluminum chlorohydrate, aluminum sulfate, ferric chloride, ferric sulfate, and ferrous sulfate monohydrate.

According to some embodiments of the disclosure, a fixed film biological system may be used in conjunction with ballasted clarifiers to treat water or wastewater. The systems and methods of the present disclosure may be particularly advantageous, for example, in treatment plants where a small footprint is required such as, for example, a retrofit for industrial plants, small flow plants or package plants, hybrid wastewater plants, combining

fixed film processes and activated sludge processes, and lagoon plants requiring nitrification. Also, this combination may be used in small flow systems that do not have significant operator interface yet require a high quality effluent. The use of a fixed film process in combination with ballasted settling is not limited to the examples given. Many uses in
5 biological and chemical treatment of wastewater or potable water are possible.

In certain embodiments, a fixed film process followed by a ballasted flocculation process may be utilized for biological treatment of water or wastewater to remove at least one of nitrogen compounds, such as nitrates, biological oxygen demand (BOD), chemical oxygen demand (COD), and phosphorus compounds. Fixed film processes may oxidize ammonia to
10 nitrate and/or reduce nitrate to nitrogen gas. Biological solids produced may then be removed in addition to dissolved, colloidal and particulate solids by the ballasted clarifiers. In certain embodiments, at least one of nitrogen compounds, such as nitrates, biological oxygen demand (BOD), chemical oxygen demand (COD), and phosphorus compounds may be removed prior to disinfection to provide potable water or drinking water to distribute it to a
15 water supply grid.

Ballasted flocculation systems may comprise the addition of a coagulant, a ballast and, optionally, a flocculant to improve the removal of dissolved, colloidal, particulate and microbiological solids. In certain embodiments, the coagulant may be optional. For example, ballast and flocculant may be added, without coagulant. In other embodiments,
20 ballast may be added without coagulant and flocculant. In some embodiments, ballast and coagulant may be added, without flocculant. In certain embodiments, a magnetic ballast may be used.

The enhanced settlability of these ballasted solids may provide for a small clarification step, which may allow for a small footprint system comprising biological and
25 clarification steps. Recirculation of solids, either ballasted solids or ballast-free solids, to at least one of the ballasted flocculation processes, such as the ballast mixing step, and to the fixed film process can further enhance the reliability of the overall system. These features may be utilized in existing wastewater treatment plants, small flow plants or package plants, combined sewer overflow (CSO) treatment plants, new plants that require a small footprint,
30 hybrid treatment plants (fixed film and activated sludge), and lagoon treatment plants requiring nitrification. One benefit is that an existing clarifier downstream of a fixed film process is readily convertible to a ballasted system using the system of the present disclosure.

Conventional clarifiers may be even more readily convertible if the ballasted system uses a magnetic material, for example, magnetite, as the ballast.

In some embodiments of the disclosure, a system for treating wastewater is provided. The system comprises a fixed film reactor fluidly connected to a source of wastewater and configured to provide a fixed film effluent. A fixed film biological system may be employed which may comprise one or more fixed film reactors, which are utilized in parallel or in series, and in which one or more of the fixed film reactors is operational at a given point in time. In certain embodiments, the fixed film effluent may comprise about 50 mg/l to about 300 mg/l of biological solids. The fixed film effluent may flow to a ballasted flocculation system in which a source of coagulant may be fluidly connected to the fixed film effluent and configured to provide a coagulated effluent. The source of coagulant may be optional. A source of ballast may be fluidly connected to the coagulated effluent and configured to provide a ballasted effluent. In some embodiments, the source of ballast may be fluidly connected to at least one of the fixed film effluent or the coagulated effluent. The source of ballast may comprise a powdered ballast. The ballast may not be in a liquid such that it may be added in dry powdered form. In some embodiments, the ballast may be added by an operator or by machinery, such as by a dry feeder. It is to be understood that the source of ballast being fluidly connected to the fixed film effluent or the coagulated effluent, or to any effluent or wastewater stream of the system, may comprise the source of ballast may be in a dry (non-liquid) or powdered form. A clarifier may be fluidly connected to the ballasted effluent, the clarifier comprising a treated effluent outlet and a ballasted solids outlet and configured to separate a treated effluent from a ballasted solids. The ballasted solids outlet of the clarifier may be fluidly connected to at least one of the coagulated effluent and the fixed film reactor. In some embodiments, the ballasted solids outlet may be fluidly connected to the source of ballast.

Optionally, a source of flocculant may be fluidly connected to the ballasted effluent. At least one of the sources of coagulant, ballast and flocculant may be provided in line to a fixed film effluent stream. Alternately, tanks may be used such that the fixed film effluent flows to a coagulant tank, into which a coagulant is added from a source of coagulant. The coagulated effluent may then flow to a ballast tank, into which a ballast is added from a source of ballast. The ballasted effluent may then flow to a flocculant tank, into which a flocculant is added from a source of flocculant. The flocculant effluent may then flow to the clarifier. In certain embodiments, a flocculant tank and source of flocculant may not be

included in the ballasted flocculation system, and the ballasted effluent may flow directly to the clarifier. In some embodiments, a coagulant tank and source of coagulant may not be included in the ballasted flocculation system.

As discussed above, the ballast may be a magnetic ballast. The magnetic ballast may comprise an inert material. The magnetic ballast may comprise a ferromagnetic material. The magnetic ballast may comprise iron-containing material. In certain embodiments, the magnetic ballast may comprise an iron oxide material. For example, the magnetic ballast may comprise magnetite (Fe_3O_4). The magnetic ballast may have a particle size that allows it to bind with biological flocs to provide enhanced settling or clarification, and allow it to be attracted to a magnet so that it may be separated from the biological flocs. The particle size of the magnetic ballast may be less than about 100 micrometers (μm). The particle size of the magnetic ballast may be less than about 40 μm . The particle size of the magnetic ballast may be less than about 20 μm .

Sand ballasted systems often implement larger ballast size to effectively recover the ballast. Ballast is also non-magnetic. Sand ballasted systems have also implemented the use of cleaning agents to separate the biological solids from the sand particles. This could be a result of a large surface for bacteria to attach, requiring more than shearing forces of a vortex mechanism alone to remove biological solids from the sand particle surface, or the need to dissolve chemical bonds that assist in the binding of the ballast.

Unlike sand based ballast that requires growth of floc around relatively large size sand particles, magnetite ballast can be used with small size, such as less than about 100 μm , allowing for the magnetite particles to impregnate existing floc. The result may be an enhanced separation of flocculants. The ballasted effluent or the flocculant effluent may be directed to at least one clarifier where ballasted solids, such as magnetite ballasted solids, may be removed by gravity at an enhanced rate greater than conventional gravity clarifiers. The clarifier, being configured to provide a treated effluent and a ballasted solids, may be fluidly connected to at least one of the source of ballast, the coagulated effluent, and the fixed film reactor. In certain embodiments, the ballasted solids outlet of the clarifier may be fluidly connected to at least one of the coagulated effluent and the fixed film reactor. This may allow at least a portion of the ballasted solids to return to the fixed film biological system and to the source of ballast, for example, the ballast tank connected to a source of ballast. A portion of the biological solids may also be removed from the system. This may involve utilizing a magnetic separation apparatus, which may allow recovery of magnetic particles,

which would not be feasible with, for example, sand particles. In certain embodiments, mechanical shearing may be employed to shear the biological solids prior to ballast recovery, for example, prior to magnetite recovery. In some instances, such as re-seeding and high flow events, a portion of the settled biological solids may be recycled to the front of the fixed film system. These solids may either be ballasted or solids stripped of magnetite through the magnetic separation. In certain embodiments, such as small-scale operations, it may not be necessary or feasible to recover the ballast, such as the magnetic ballast from the system.

In certain embodiments, the system may be configured to treat between about 200 gallons per day per square foot of a surface area of the clarifier to about 2,000 gallons per day per square foot of the surface area of the clarifier. In certain embodiments, the system may be configured to treat between about 200 gallons per day per square foot of a surface area of the clarifier to about 6,000 gallons per day per square foot of the surface area of the clarifier. In certain other embodiments, the system may be configured to treat between about 100 gallons per day per square foot of a surface area of the clarifier to about 36,000 gallons per day per square foot of a surface area of the clarifier.

In certain embodiments, a ballasted recovery system may be positioned downstream of the ballasted solids outlet of the clarifier. The ballasted recovery system may be positioned upstream of at least one of the source of ballast and the fixed film reactor.

In certain embodiments, the use of a magnetic ballast provides advantages over use of other ballast materials. For example, the use of a magnetic ballast provides for enhanced removal of biological solids from the ballast. For example, a magnetic drum may be used to separate the biological solids from the magnetic ballast. Optionally, mechanical shearing may be utilized prior to separation. This process may sufficiently remove the biological solids from the ballast. Recirculation of settled solids to the reaction tanks further enhances performance and reliability while the optional recycle to the fixed film system, whether with ballasted or ballast-free solids, allows for additional flexibility for treatability and recovery in process upsets or startups. In certain embodiments, cleaning solutions may be unnecessary in separating ballast from the biological solids.

A system for treating wastewater is shown in FIG. 1. A source of wastewater, stream 1, which may be screened wastewater or primary clarification effluent, enters fixed film biological system or fixed film reactor 4. Fixed film reactor 4 may comprise a moving bed bioreactor, a trickling filter, or a rotating biological contactor, for example. Soluble substrate may be oxidized or reduced to biological solids in the form of, for example, a slough, from

the fixed biomass on an inert carrier or sheet of fixed film reactor 4. Aeration may be supplied in aerobic zones to supply oxygen and mixing for the reactor 4. In the case of anaerobic or anoxic based systems, mixers can be provided to keep the system fully mixed. Fixed film effluent exits the reactor 4. Fixed film effluent comprises wastewater and solids produced in reactor 4. Fixed film effluent enters a series of feed reaction areas which may be inline or utilize tanks.

Source of coagulant 7, such as metal or prehydrolyzed metal salt, is added in reaction area 6 to provide a coagulated effluent. Following coagulation addition 6, flow continues on to ballast reaction area 8. Source of ballast, is introduced to provide a ballasted effluent. The source of ballast may comprise raw ballast 9, recycled or recovered ballast 10, recycled ballasted solids 11, or combinations thereof. The ballast may comprise a magnetic material. The ballast may comprise a ferrous material. The ballast may comprise magnetite (Fe_3O_4). The ballast may be in powdered form. Raw ballast 9, or fresh ballast, is ballast that has not before been introduced to the waste system. Recycled or recovered ballast 10 is ballast that is separated from solids in another part of the system, for example, recovery system 20, described below, and recycled to the ballast reaction area. Ballasted solids comprise biological solids impregnated or partially impregnated with ballast. Recycled ballasted solids 11 are ballasted solids returned to the ballast reaction area 8 from an outlet of the clarifier 15 without first being introduced to a recovery system 20 for separation.

After ballast addition 8, source of flocculant 13 may optionally be added in flocculant reaction area 12 to further flocculate solids and ballasted solids prior to being introduced into clarifier 15. Flocculant 13 may comprise a polymer.

As discussed below, clarifier 15 incorporated into the wastewater treatment system may be a converter or retrofitted clarifier. The details and particular components of the clarifier may be chosen by a person of ordinary skill in the art as required. The clarifier may, for example, comprise lamella. The clarifier may be configured to separate treated effluent 16 from ballasted solids 24 and comprises outlet 26 for treated effluent 16 and outlet 28 for ballasted solids. Solids settle in clarifier 15 and separated treated effluent 16 continues on to further disinfection if required. A portion of the settled solids may be recycled ballasted solids 11 returned to ballast reaction area 8. In addition or in the alternative, another portion of the ballasted solids 23 may be recycled to fixed film system 4.

At least a portion of settled solids 17 may be introduced into a ballast recovery system 20. Optionally, settled solids 17 may first be introduced to mechanical shearing device 19 to

aid in breaking up the ballast and non-ballast components of the settled solids. Alternatively, the mechanical shearing device 19 may be by-passed by stream 18. The ballast recovery system 20 may comprise a magnetic separator. For example, the separator may be a wet drum magnetic separator. In a wet drum magnetic separator, magnetic ballast adheres to the surface of a rotatable drum and is directed to a separate outlet from nonmagnetic components, or ballast-free solids, of the feed. Stripped solids may comprise waste sludge 21 that exits the system 20 for further solid waste treatment and disposal. A portion of these stripped solids, or ballast-free solids, may optionally be recycled to fixed film system 4 via optional feed line 22. It should be understood that ballast-free solids refers to solids that have a majority portion of the ballast removed from the solids. In some embodiments, at least about 90% of the ballast has been removed. In other embodiments, at least about 95% of the ballast has been removed.

Additional optional components include clarifier 3 fluidly upstream of fixed film system 4, and bypass line 2 which may allow stream 1 to bypass fixed film system 4 if necessary, for example, during a high flow event, such as a rainfall or storm event.

In certain embodiments of the present disclosure, a method of treating a wastewater may be provided. The wastewater may be treated at a rate of between about 200 gallons per day per square foot of a surface area of the clarifier to about 2,000 gallons per day per square foot of the surface area of the clarifier. In certain embodiments, the system may be configured to treat between about 200 gallons per day per square foot of a surface area of the clarifier to about 6,000 gallons per day per square foot of the surface area of the clarifier. In certain other embodiments, the system may be configured to treat between about 100 gallons per day per square foot of a surface area of the clarifier to about 36,000 gallons per day per square foot of a surface area of the clarifier. In certain embodiments, the rate may be an average rate over a predetermined period of time. The method may comprise introducing a source of wastewater to a fixed film reactor to provide a fixed film effluent. The fixed film effluent may comprise about 50 mg/l to about 300 mg/l of biological solids. In other examples, the fixed film may comprise about 50 mg/l to about 2,000 mg/l. The method may further comprise optionally adding a coagulant to provide a coagulated effluent. In some embodiments, the coagulant may be added to the fixed film effluent. The method may further comprise adding a ballast to provide a ballasted effluent. In some embodiments, the ballast may be added to at least one of the fixed film effluent and the coagulated effluent. The ballast may comprise a magnetic material. The ballast may comprise magnetite. The

method may further comprise separating the ballasted effluent into a treated effluent and a ballasted solids in a clarifier. The ballasted solids may include a small amount of residual ballast-free solids and other residual components, as separation processes and ballasting processes will never be perfectly complete. The method may further comprise separating the ballasted solids into a recovered ballast and a ballast-free solids. Once again, the recovered ballast may also comprise some residual non-ballast components. Likewise, the ballast-free solids may comprise some residual ballast. The method may further comprise adding the recovered ballast to the coagulated effluent.

The method may also further comprise adding a flocculant to the ballasted effluent. The method may also further comprise adding a portion of the ballast-free solids to at least one of the source of wastewater, the fixed film effluent, and the coagulated effluent. The method may also further comprise adding a portion of the ballasted solids to at least one of the source of wastewater, the fixed film effluent, and the coagulated effluent. The method may also further comprise adding a portion of the ballast-free solids to at least one of the source of wastewater and the coagulated effluent. The method may also further comprise adding a portion of the ballasted solids to at least one of the source of wastewater and the coagulated effluent.

Wastewater treatment systems and methods such as those disclosed above may be accomplished by constructing reaction tanks directly inside a clarifier. This clarified unit may be constructed as part of a new wastewater treatment system or may be constructed as part of a retrofitting. Such a configuration may address potential obstacles to the disclosed wastewater systems and methods including locating the reaction tanks, and minimizing the length of pipe run between the reaction tanks and clarifier. The tanks could be constructed of mild steel, concrete, stainless steel, fiberglass, or the like. Construction of reaction tanks directly inside a clarifier would minimize the footprint and capital cost associated with installation of the disclosed system, particularly in cases where existing clarifiers would require modifications to make them work better in a ballasted flocculation system. These existing clarifiers are often oversized for the task of settling ballasted floc, and therefore the extra space may be used to incorporate reaction tanks by installing the reaction tanks inside the clarifiers. This effectively reduces the hydraulic retention time of the over-sized clarifiers, minimizes the required footprint of the water treatment system installation, and provides the opportunity to use common wall construction to further reduce capital cost.

Clarifiers designed for ballasted clarification do not typically include scum collection systems, so there would be no interference of the reaction tanks with such a system.

A schematic of an embodiment of a system is shown in FIG. 2. System 200 comprises clarifier 205. Integrated into clarifier 205 may be coagulation tank 210, ballast feed tank 215, and flocculation tank 220. Source of coagulant 235 may be fluidly connected to coagulation tank 210. Source of ballast 240 may be fluidly connected to ballast feed tank 215. The ballast may comprise a magnetic material. For example, the ballast may comprise magnetite. The magnetite may be in powdered form. Source of ballast 240 may be introduced to ballast feed tank 215. For example, the delivery may be accomplished automatically through a control system or manually. The delivery of ballast may be continuous or it may be intermittent. Likewise, for coagulant and flocculant delivery may be automatic or manual, and continuous or intermittent. Optionally, source of flocculant 245 may be fluidly connected to an optional flocculation tank 220. The flocculant may comprise, for example, a polymer. While the present embodiment has all three tanks incorporated into the clarifier, other combinations are possible. For example, coagulant tank 210 may be located outside clarifier 205, and flocculant tank 220 is optional.

Similar to FIG. 1, effluent 230 may enter coagulation tank 210, which may provide coagulated effluent stream 250. Stream 250 may enter ballast mixing tank 215, which may provide ballasted effluent stream 255. Stream 255 may enter flocculation tank 220, which may provide flocculated effluent stream 260. Stream 260 may then enter the clarification portion of clarifier 205. Treated effluent stream 265 may exit clarifier 205. Meanwhile, a separate ballasted solids stream 270 may exit clarifier 205 at a different outlet from that of treated effluent stream 265. A portion of the ballasted solids may be diverted to a returned ballasted solids stream 275 that may feed ballast feed tank 215. At least a portion of the ballasted solids stream 270 may be directed to ballast recovery system 280. The ballast recovery system 280 may produce a recovered ballast stream 290 which may be directed to ballast feed tank 215. The ballast recovery system 280 may produce a ballast-free solids stream 285, or solids waste stream, directed for further processing or returned to a part of the waste treatment system.

In certain embodiments of the present disclosure, a method of retrofitting a wastewater treatment system may be provided. The wastewater treatment system may comprise a fixed film bioreactor and a clarifier positioned downstream of the fixed film bioreactor. The clarifier may comprise a solids outlet. The method may comprise installing a

coagulation tank in the clarifier. The method may further comprise installing a ballast feed tank connected downstream of the coagulant tank in the clarifier. The method may further comprise connecting the solids outlet of the clarifier to the ballast feed tank. The method may further comprise installing a ballast recovery system downstream of the solids outlet of the clarifier and upstream of the ballast feed tank. The method may further comprise installing a flocculation tank in the secondary clarifier connected downstream of the ballast feed tank.

The function and advantage of these and other embodiments of the systems and techniques disclosed herein will be more fully understood from the example below. The following example is intended to illustrate the benefits of the disclosed treatment approach, but do not exemplify the full scope thereof.

EXAMPLES

EXAMPLE 1

A wastewater stream from a source of wastewater was delivered to three fixed film moving bed bioreactor (MBBR) tanks in series after passing through coarse screening, grit removal, and a fine screen. The screened water was pumped to the MBBR tanks at an average flow rate of 2.1 gallons per minute (GPM). The flow then passed through a 6 foot diameter by 7 foot deep secondary clarifier. Samples were taken from the effluent prior to being passed through the secondary clarifier. The samples were placed into liter beakers with coagulant dosages of 10 to 60 ppmv, with ferric chloride as the coagulant. Magnetite at 10 g/L was added to each beaker. The samples were mixed for three to six minutes, and then allowed to settle. All samples settled rapidly in 15 to 30 seconds, with settling results ranged from 0.2 to 2.9 mg/L effluent total suspended solids. All effluent in the beakers appeared clear at each dose of coagulant.

These results may be compared to a fixed film MBBR system that is followed by a secondary clarifier in which about 90 ppmv of ferric chloride is used, which results in an effluent of the clarifier having 25 to 35 mg/L total suspended solids.

These results show that using a fixed film MBBR process in conjunction with a magnetic ballast system enhanced the quality of the treated water, reducing the total suspended solids. This process also required less coagulant to be used in the process. This system provides enhanced treatment of the water as well as provide cost savings in terms of using less coagulant than a conventional system.

EXAMPLE 2

Wastewater was processed through a treatment system comprising a trickling filter and a secondary clarifier. The flow rate of wastewater entering the trickling filter was about 600 GPM to about 700 GPM. A coagulant (alum) was added to the effluent of the trickling filter at concentrations ranging from about 100 ppmv to about 300 ppmv. Fifty GPM of effluent from the trickling filter was diverted to a process comprising a ballasted flocculation system in which magnetite was added to the trickling filter effluent.

Data regarding biological oxygen demand (BOD) was measured for a system including a trickling filter whose effluent was either treated in a ballasted flocculation system or a secondary clarifier. Samples were taken over a two week period. This data is shown in Table 1.

Table 1.

Sample	BOD in Feed to Trickling Filter (mg/l)	BOD in Effluent after Trickling Filter into Ballasted Flocculation (mg/l)	BOD in Effluent after Ballasted Flocculation (mg/l)	BOD in Effluent from Secondary Clarifier (mg/l)
1	75	51	3	Not tested
2	87	46	4	22
3	81	28.1	9.55	12
4	Not tested	20.6	3.9	10
5	91.4	29.6	2.6	4

As shown above in Table 1, the BOD of the effluent after treatment with the ballasted flocculation system was improved over effluent that was treated with a secondary clarifier. These results demonstrate the improved treated water product that may be obtained by using the ballasted flocculation process over a conventional secondary clarifier.

Data was also collected from testing using the ballasted flocculation system and is shown in Tables 2-5.

Table 2.

Sample	Total Suspended Solids in Feed to Trickling Filter (mg/l)	Total Suspended Solids in Effluent of Trickling Filter, going into Ballasted Flocculation (mg/l)	Total Suspended Solids in Effluent after Ballasted Flocculation (mg/l)
1	117	110	3
2	127	89	73*
3	110	95	3
4	40	43	4
5	45	34	2

*In this run, no alum was added.

As shown above in Table 2, total suspended solids was decreased substantially through use of the ballasted flocculation process.

Table 3.

Sample	Total Phosphorus from Trickling Filter Effluent, going into Ballasted Flocculation (mg/l)	Total Phosphorus in Ballasted Flocculation Clarifier Effluent (mg/l)
1	5.46	0.061
2	5.34	0.131
3	4.66	0.047
4	3.97	2.36
5	4.01	0.314

As shown in Table 3, phosphorus levels were reduced through use of the ballasted flocculation process.

Table 4.

Sample	Turbidity in Trickling Filter Effluent, going into Ballasted Flocculation (NTU)	Turbidity in Effluent after Ballasted Flocculation (NTU)
1	95	3.1
2	65	8.9
3	40	12.5
4	40	4.1
5	50	Not tested

As shown in Table 4, turbidity was reduced through use of the ballasted flocculation system.

While exemplary embodiments of the disclosure have been disclosed, many modifications, additions, and deletions may be made therein without departing from the spirit and scope of the disclosure and its equivalents, as set forth in the following claims.

Those skilled in the art would readily appreciate that the various configurations described herein are meant to be exemplary and that actual configurations will depend upon the specific application for which the system and methods of the present disclosure are used. Those skilled in the art will recognize, or be able to ascertain using no more than routine experimentation, many equivalents to the specific embodiments described herein. For example, those skilled in the art may recognize that the system, and components thereof, according to the present disclosure may further comprise a network of systems or be a component of a wastewater treatment system. It is, therefore, to be understood that the foregoing embodiments are presented by way of example only and that, within the scope of the appended claims and equivalents thereto, the disclosed system and methods may be practiced otherwise than as specifically described. The present system and methods are directed to each individual feature or method described herein. In addition, any combination of two or more such features, apparatus or methods, if such features, system or methods are not mutually inconsistent, is included within the scope of the present disclosure.

Further, it is to be appreciated various alterations, modifications, and improvements will readily occur to those skilled in the art. Such alterations, modifications, and improvements are intended to be part of this disclosure, and are intended to be within the

spirit and scope of the disclosure. For example, an existing facility may be modified to utilize or incorporate any one or more aspects of the disclosure. Thus, in some cases, the apparatus and methods may involve connecting or configuring an existing facility to comprise at least one of a fixed film system, a clarifier, and a ballasted flocculation system .

5 Accordingly, the foregoing description and drawings are by way of example only. Further, the depictions in the drawings do not limit the disclosures to the particularly illustrated representations.

As used herein, the term “plurality” refers to two or more items or components. The terms “comprising,” “including,” “carrying,” “having,” “containing,” and “involving,”
10 whether in the written description or the claims and the like, are open-ended terms, i.e., to mean “including but not limited to.” Thus, the use of such terms 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. Use of ordinal terms such as
15 “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 claim 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.

20

CLAIMS

1. A system for treating wastewater comprising:
 - 5 a fixed film reactor fluidly connected to a source of wastewater and configured to provide a fixed film effluent, wherein the fixed film effluent comprises wastewater and biological solids produced in the fixed film reactor;
 - a source of coagulant fluidly connected to a coagulant tank connected downstream of the fixed film reactor configured to provide a coagulated effluent; a
 - 10 source of ballast fluidly connected to a ballast feed tank connected downstream of the coagulant tank , wherein the ballast feed tank is configured to provide a ballasted effluent and the ballast comprises magnetite; and
 - a clarifier fluidly connected to at least one of the ballast feed tank providing the ballasted effluent, the coagulant tank providing coagulated effluent, and the fixed film reactor, the clarifier comprising a treated effluent outlet and a ballasted solids
 - 15 outlet and configured to separate a treated effluent from ballasted solids.
2. The system of claim 1, further comprising a source of flocculant fluidly connected to a flocculation tank downstream of the ballast feed tank.
- 20 3. The system of claim 1, wherein the fixed film reactor comprises at least one of a moving bed bioreactor, a trickling filter, and a rotating biological contactor.
4. The system of claim 1, wherein the fixed film effluent comprises 50 mg/l to 300 mg/l of biological solids.
- 25 5. The system of claim 1, wherein the system is configured to treat between 200 gallons per day per square foot of a surface area of the clarifier to 6,000 gallons per day per square foot of the surface area of the clarifier.
- 30 6. The system of claim 1, wherein the ballasted solids outlet of the clarifier is fluidly connected to at least one of the coagulated effluent and the fixed film reactor.

7. The system of claim 6, further comprising a ballast recovery system positioned downstream of the ballasted solids outlet of the clarifier and upstream of at least one of the source of ballast and the fixed film reactor.

5 8. A method for treating a wastewater comprising:

introducing wastewater from a source of wastewater to a fixed film reactor to provide a fixed film effluent, wherein the fixed film effluent comprises wastewater and biological solids produced in the fixed film reactor;

adding a coagulant to the fixed film effluent to provide a coagulated effluent;

10 following coagulation addition further adding a ballast in a ballast mixing step in a ballast feed tank downstream of a coagulant tank to provide a ballasted effluent, wherein the ballast comprises magnetite;

introducing the ballasted effluent into a clarifier and separating the ballasted effluent into a treated effluent and ballasted solids in the clarifier;

15 separating the ballasted solids into a recovered ballast and a ballast-free solids; and

adding the recovered ballast to the coagulated effluent.

20 9. The method of claim 8, further comprising adding a flocculant to the ballasted effluent.

10. The method of claim 8, further comprising adding a portion of the ballast-free solids to at least one of the influent of the fixed film reactor, the fixed film effluent, and the coagulated effluent.

25 11. The method of claim 8, further comprising adding a portion of the ballasted solids to at least one of the influent of the fixed film reactor, the fixed film effluent, and the coagulated effluent.

30 12. The method of claim 8, wherein the fixed film effluent comprises 50 mg/l to 300 mg/l of biological solids.

13. The method of claim 8, wherein the wastewater is treated at a rate of between 200 gallons per day per square foot of a surface area of the clarifier to 6,000 gallons per day per square foot of the surface area of the clarifier.

5 14. A method for retrofitting a wastewater treatment system comprising a fixed film bioreactor and a clarifier positioned downstream of the fixed film bioreactor and comprising a solids outlet, the method comprising:

installing a coagulation tank in the clarifier, wherein the coagulation tank is connected downstream of the fixed film reactor;

10 installing a ballast feed tank connected downstream of the coagulant tank in the clarifier; wherein the ballast comprises magnetite;

the clarifier fluidly connected to at least one of the ballast feed tank, the coagulant tank, and the fixed film reactor, and

connecting the solids outlet of the clarifier to the ballast feed tank.

15 15. The method of claim 14, further comprising installing a ballast recovery system downstream of the solids outlet of the clarifier and upstream of the ballast feed tank.

20 16. The method of claim 14, further comprising installing a flocculation tank in a secondary clarifier connected downstream of the ballast feed tank.

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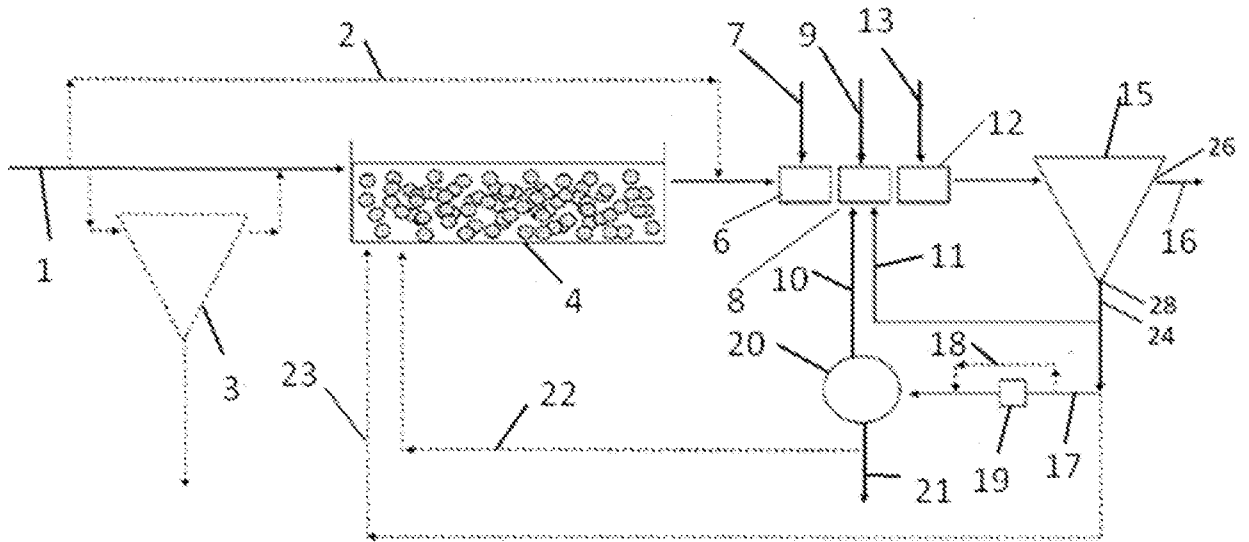


FIG. 1

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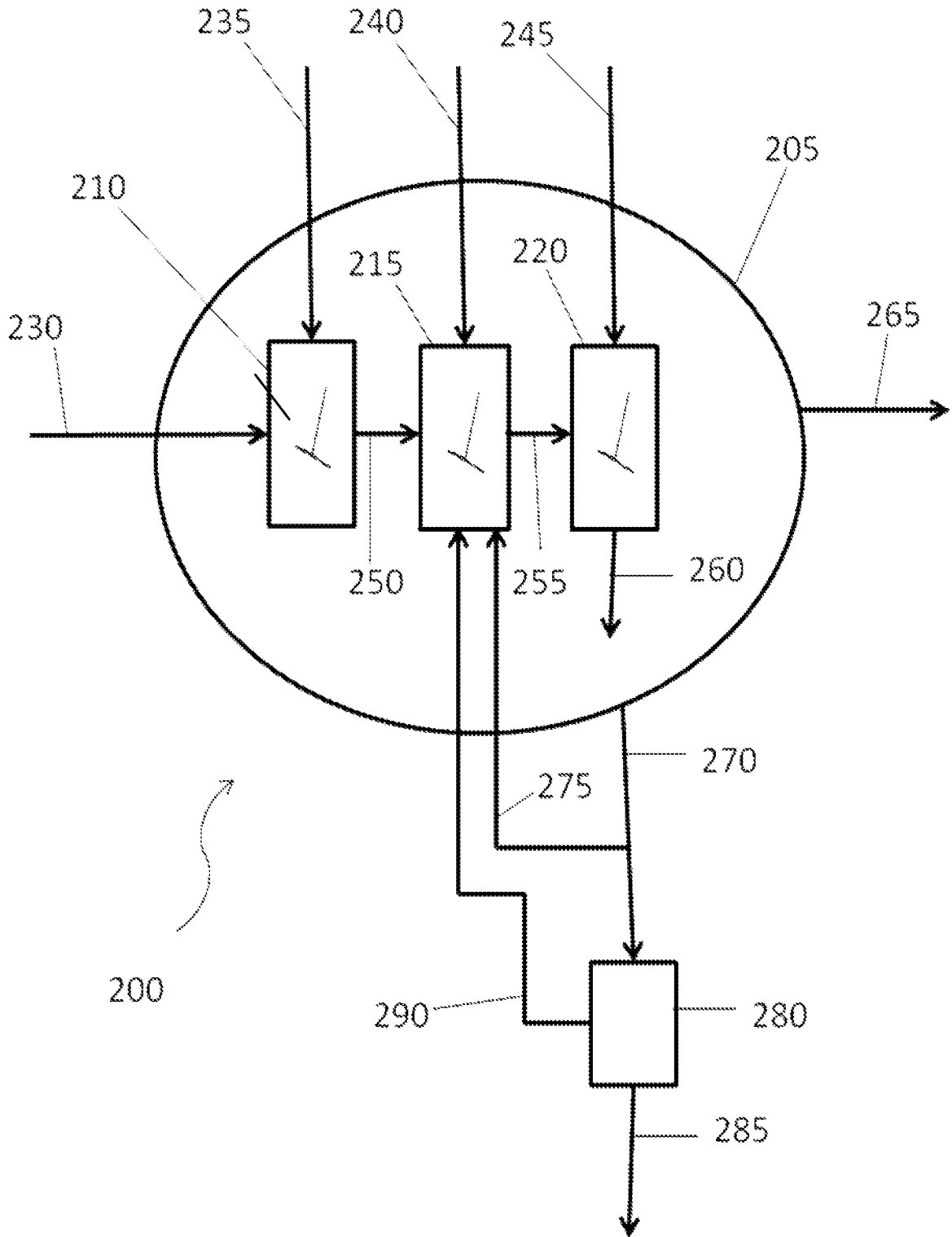


FIG. 2

