



(51) International Patent Classification:

C02F 3/30 (2006.01)

(21) International Application Number:

PCT/US2012/067358

(22) International Filing Date:

30 November 2012 (30.11.2012)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

61/565,941 1 December 2011 (01.12.2011) US

(71) Applicant: PRAXAIR TECHNOLOGY, INC. [US/US];
39 Old Ridgebury Road, Danbury, CT 06810 (US).

(72) Inventors: FABIYI, Malcolm E.; 921 E. 40th St., Apt. 2E, Chicago, IL 60653 (US). NOVAK, Richard A.; 3820 Celeste Lane, Naperville, IL 60564 (US). MARX, Randall B.; 21 W 710 Glen Valley Dr., Glen Ellyn, IL 60137 (US).

(74) Agents: HAMPSCHE, Robert J. et al; Praxair, Inc., 39 Old Ridgebury Road, Danbury, CT 06810 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM,

AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

with ~~out~~ ~~of~~ ~~the~~ ~~benefit~~ ~~of~~ ~~the~~ ~~priority~~ ~~claim~~ ~~to~~ ~~be~~ ~~republished~~ ~~upon~~ ~~receipt~~ ~~of~~ ~~that~~ ~~report~~ (Rule 48.2(g))

(54) Title: METHOD AND SYSTEM FOR OZONE VENT GAS REUSE IN WASTEWATER TREATMENT

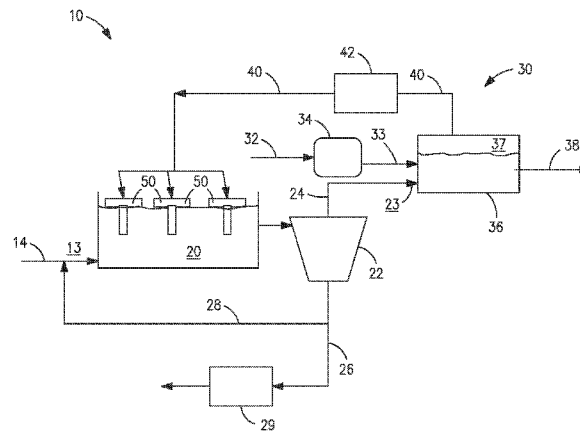


FIG. 1

(57) Abstract: A system and method for ozone vent gas reuse is provided. The disclosed system and method involve controlling or conditioning the ozone vent gas stream or degassing unit vent gas stream and directing the stream to a mechanically agitating contactor in an aerobic section of the wastewater treatment system. The oxygen content of the vent gas stream is controlled so as to ensure sufficient oxygenation to the aerobic section of the wastewater treatment system. Control may be effected by adjusting the oxygen content of the vent gas stream in response to sensor or measurement inputs characterizing the gas contents of the vent gas stream or the dissolved oxygen level in the aerobic section of the wastewater treatment plant. Adjusting the oxygen content of the vent gas stream may be accomplished by: adjusting the flow of the oxygen containing feed stream to the ozone generator; adjusting the power supplied to the ozone generator; or adjusting the flow of a make-up oxygen containing stream to the vent gas stream. The volumetric flow of the vent gas stream to the aerobic section may also be controlled by adjusting the rotational speed of the mechanically agitating contactor in an aerobic section of the wastewater treatment system.



Method and System for Ozone Vent Gas Reuse in Wastewater Treatment

Field of the Invention

[0001] The present invention relates to a method and system for wastewater treatment, and more particularly, a method and system for the reuse of the vent gas from an ozone generator or degassing unit in a wastewater treatment plant to provide some or all of the oxygenation requirements to a section of the wastewater treatment plant.

Background

[0002] Generally, the use of ozone gas in water treatment plants has been around for many years and its use appears to be increasing. For example, ozone disinfection is used in many medium to large sized treatment plants. In addition, ozone treatment is also commonly used for taste, odor control and color control. Other uses of ozone in water treatment plants include treatment of sludge in an aeration basin of a wastewater treatment plant as disclosed in U.S. Patent Nos. 7,309,432 issued December 18, 2007 and 6,086,766 issued July 11, 2000. Other more recent applications of ozone include foam or bulking control as disclosed in US Patent No. 7,513,999 issued April 7, 2009 as well as treatment of streams in digesters, or other sections of wastewater treatment plant as disclosed in US Patent Application Serial No. 13/685,330.

[0003] The use of ozone for tertiary treatment at wastewater plants is increasing in popularity due to the rising demand for reuse water. As a strong oxidant, ozone is an effective disinfectant that produces discharge water free of known toxic disinfection byproducts with the exception of those that result from ozonation of high-bromine waters. Ozone is also cost-effective means to achieve color removal without the addition of chemicals, or generation of chemical sludge.

[0004] As ozonation of a filtered secondary effluent enables reuse, ozone is popular in areas of "water stress" where usage rates are high relative to water flows and storage in natural systems such as lakes and rivers. In China, for

example, the annual water usage represents about 20% of the total available supply, however, due to acquisition cost constraints and pollution, the nation's water supply deficit has been estimated at over 40 billion cubic meters.

[0005] Typically, the selection of ozone systems and technologies for use in wastewater treatment plants are based on the total capital and operating costs of the ozone treatment system balanced against the benefits realized through the use of the ozone treatments and in view of the regulatory mandates or requirements in discharging effluents. Therefore, the selection of ozone technology that offers the best economic value is of paramount importance, regardless of the size of the wastewater treatment plant.

[0006] The typical capital investment for an ozone generator and contactor, and ozone destruct unit as well as the operating and maintenance expenses associated with use of various ozone technologies in wastewater treatment plants can be quite significant. In addition, since ozone is extremely irritating and toxic above certain concentrations, any residual ozone in the off-gases from the contactor is typically destroyed using an ozone destruct system or unit to prevent worker exposure to ozone gases.

[0007] Oxygen is commonly used as a feed gas for generating ozone gas, which is subsequently used for disinfection or oxidation of water supplies. Oxygen may be generated on-site as a gas or liquid or purchased in bulk as liquid oxygen.

Numerous water and wastewater treatment plants in the United States are using ozone for water treatment, with a majority generating ozone from purchased oxygen. The majority of the annual operating costs for ozone systems within wastewater treatment plants include very high power consumption associated with the production of ozone and costs associated with the supply of oxygen.

[0008] Ozone can be produced from oxygen in the air or from high-purity gaseous oxygen. This is achieved by several methods, although the most common technique is flowing the oxygen containing feed through a corona discharge with dielectric barrier. Ozone is produced when a dry oxygen or air gas stream is subjected to a high-voltage/high-density electrical current, which provides the energy to drive the reaction. The field acts between two electrodes separated by a

dielectric, forming a gap across which the energy discharge occurs. Oxygen-fed ozone generators will produce more ozone for a given power input and produce higher ozone concentrations in the product gas, as compared to operating on air. Air-based ozonation systems also require additional capital equipment including a drier as well as a compressor.

[0009] Liquid oxygen suitable for use in the generation of ozone for the treatment of water should preferably have an oxygen content of at least about 99.0 percent, by weight with a water content not exceeding about 7.8 parts per million (ppm), equivalent atmospheric dew point of -80°F and a total hydrocarbon content (e.g. methane, ethane, acetylene, and other hydrocarbons) of less than about 40 ppm. Other impurities such nitrogen, argon, and other inert gases may also be present in small amounts.

[0010] Many current ozonation systems typically use oxygen as the feed gas and only about 5-15% of the oxygen in the feed stream is converted to ozone during ozone generation. The balance is typically vented following destruction of the residual ozone and serves no useful purpose, except that a small amount has been used for re-aeration of the effluent. While several technologies have been developed to recycle the oxygen present in the product gas, few have been commercialized successfully (See US Patent Nos. 4,132,637 and 4,256,574). Also, recovery and resale of the ozone vent gas is not a viable option due to the costs associated with drying, purifying, compressing and shipping the waste gas.

[0011] What is needed therefore, are systems and processes configured for use in wastewater treatment plants that mitigate the capital and operating expenses associated with use of ozone technologies, and in particular, effectively and efficiently re-use of the ozone vent gases to meet the oxygenation requirements in other sections of the wastewater treatment plant. In this manner, the wastewater treatment plant can realize multiple benefits from the use of an ozone treatment system thereby off-setting the high operating costs of the ozone treatment system.

Summary of the Invention

[0012] The present invention may be characterized as a method for ozone vent gas reuse in a wastewater treatment system comprising the steps of: (i) directing an oxygen containing feed stream to an ozone generator; (ii) operating the ozone generator to produce an ozone containing gas stream; (iii) directing the ozone containing gas stream to an ozone treatment system within the wastewater treatment system to produce an ozone treated effluent and an ozone vent gas stream; and (iv) directing the ozone vent gas stream to a mechanically agitating contactor in an aerobic section of the wastewater treatment system. The ozone vent gas stream may be mixed or combined with a make-up oxygen containing stream and the combined stream is then directed to the aerobic section of the wastewater treatment system. A key aspect of the present method of ozone vent gas reuse is the control of the oxygen content in the ozone vent gas stream. Preferably, the oxygen content of the ozone vent gas stream is controlled so as to ensure sufficient oxygenation to the aerobic section of the wastewater treatment system by adjusting the oxygen content of the ozone vent gas stream in response to sensor or measurement inputs characterizing the gas contents of the ozone vent gas stream or the dissolved oxygen level in the aerobic section of the wastewater treatment section.

[0013] Adjusting the oxygen content of the ozone vent gas stream may be accomplished by one or more of the following techniques: adjusting the flow of the oxygen containing feed stream to the ozone generator; adjusting the power supplied to the ozone generator; or adjusting the flow of a make-up oxygen containing stream to the ozone vent gas stream. Alternatively, the volumetric flow of the ozone vent gas stream to the aerobic section of the wastewater treatment system may be controlled is controlled by adjusting the rotational speed of the mechanically agitating contactor in an aerobic section of the wastewater treatment system.

[0014] The present invention may also be characterized as a ozone vent gas reuse system for a wastewater treatment plant comprising: (a) an oxygen containing feed stream; (b) an ozone generator configured to receive the oxygen containing feed stream and produce an ozone containing gas stream; (c) an ozone contactor for contacting an effluent with the ozone containing gas stream to produce an ozone treated effluent and an ozone vent gas stream; (d) an ozone destruct system configured to receive the ozone vent gas stream and destroy any ozone contained in the ozone vent gas stream; (e) a supplemental oxygen delivery conduit coupling the ozone vent gas stream to a mechanically agitating contactor in an aerobic section of the wastewater treatment plant; and (f) a control unit for controlling the oxygen content of the ozone vent gas stream so as to ensure sufficient oxygenation to the aerobic section of the wastewater treatment system by adjusting the oxygen content of the ozone vent gas stream in response to sensor or measurement inputs characterizing the gas contents of the ozone vent gas stream or the dissolved oxygen level in the aerobic section of the wastewater treatment section. Preferably, the oxygen content of the ozone vent gas stream is controlled so as to ensure sufficient oxygenation to the aerobic section of the wastewater treatment plant by adjusting the flow of the oxygen containing feed stream to the ozone generator; adjusting the power supplied to the ozone generator; or adjusting the flow of a make-up oxygen containing stream to the ozone vent gas stream; or any combinations of the above-identified techniques.

[0015] Finally, the present invention may be characterized as a method for supplying supplemental oxygen in a wastewater treatment system comprising the steps of: (i) directing an oxygen or ozone containing sludge stream within the wastewater treatment system to a degassing unit; (ii) separating an oxygen containing off-gas from the sludge stream to produce a supplemental oxygen containing gas stream; and (iii) directing the supplemental oxygen containing gas stream to an aerobic, anaerobic or anoxic section of the wastewater treatment system. The oxygen content of the supplemental oxygen containing gas stream is controlled in response to sensor or measurement inputs characterizing the gas contents of the ozone vent gas stream.

Brief Description of the Drawings

[0016] The above and other aspects, features, and advantages of the present systems and methods will be more apparent from the following, more detailed description thereof, presented in conjunction with the following drawings, wherein:

[0017] Fig. 1 is a schematic illustration of an embodiment of a system for ozone vent gas reuse in accordance with the present invention; and

[0018] Fig. 2 is a schematic illustration of another embodiment of a system for ozone related gas reuse in accordance with the present invention.

Detailed Description

[0019] Turning now to Fig. 1, there is shown a schematic illustration of one embodiment of the present system and method for ozone vent gas reuse in an aerobic section of a wastewater treatment system.

[0020] As seen therein, the wastewater treatment system 10 includes an intake conduit 14 adapted to direct an influent 13 of wastewater to an aerobic section 20 of the wastewater treatment system 10. The aerobic section 20 of the wastewater treatment system 10 can include an activated sludge basin or other reactor intended configured for the purpose of using microbial life and aerobic processes to effect the removal of waste from water. The illustrated system also includes one or more clarifiers 22 downstream of the aerobic section 20 adapted to separate at least some liquid effluent from a sludge flow, an output conduit 24 for transporting the liquid effluent 23; a waste activated sludge (WAS) line 26 configured to send waste sludge to waste tank 29; and a return activated sludge (RAS) line 28 adapted to transport and return a portion of the separated sludge stream back to the aerobic section 20 of the wastewater treatment system via intake conduit 14.

[0021] The effluent 23 is directed to a tertiary ozone treatment system, illustrated as an ozone disinfection system 30 that includes an oxygen containing feed stream 32, an ozone generator 34, an ozone containing stream 33, an ozone contactor tank 36, and an ozone vent gas stream. The disinfected effluent 38 is removed

from the ozone contacting tank 36 after typically about 1 to 30 minutes of residence time and is available for various reuses. The off-gases from the ozone disinfection system 30 comprise the ozone vent gas stream 40 that is directed from the headspace 37 of the ozone contactor tank 36 to an ozone destruct unit 42 to destroy residual ozone in the ozone vent gas stream 40. From there, the ozone vent gas stream 40 is directed to the aerobic section 20 of the wastewater treatment system 10 via a supplemental oxygen delivery conduit coupling the vent gas stream to one or more aeration/oxygenation units 50 where it is used to oxygenate the contents 44 of the aerobic section 20.

[0022] Although not shown, the present system also employs a microprocessor based control unit operatively coupled to the ozone generator 34, the one or more aeration/oxygenation units 50, the oxygen feed stream 32 and a plurality of sensors or measurement devices (not shown) characterizing the gas contents (e.g. oxygen content, nitrogen content, carbon dioxide content, ozone content, etc.), pressures, and/or temperatures in the ozone contacting tank 36, the ozone vent gas stream 40, and the aerobic section 20 of the wastewater treatment system 10.

[0023] The reuse of ozone vent gas, containing elevated oxygen concentration compared to the 20.9% oxygen concentration in air, offers the following advantages: (i) lower power costs and overall operating costs compared to air-based aeration; (ii) utilizes an oxygen gas source that is essentially free as it would otherwise be wasted from the ozone contactor; and (iii) highly flexible aeration solution that can meet a higher range of oxygen uptake rates (OUR) and dissolved oxygen (DO) requirements compared to air-based aeration solutions.

[0024] In regard to the lower power costs and overall operating costs of the ozone vent gas reuse solution compared to standard air-based aeration solutions, it is well known that electrical power is a major operating cost and aeration power typically consumes more than half of the electrical power in a wastewater treatment plant. Oxygen based aeration, including aeration with ozone vent gas, typically uses less on-site power compared to air based aeration systems. For example, while modern fine-bubble diffuser systems used in many air-based aeration systems have a typical clean water aeration efficiency (SAE) of about 4.2

kg/kWh, a surface based oxygen aerator such as the I-SOTM oxygen-based aerator, available from Praxair, Inc., has demonstrated an SAE with high purity oxygen of up to 6.2 kg/kWh under typical conditions.

[0025] Another component of operating cost for oxygen-based aeration is the cost of purchased oxygen. However, when using the ozone vent gas, the cost of purchased oxygen is essentially free as the oxygen in the ozone vent gas was formerly a wasted product. An additional advantage to oxygen-based aeration compared to air-based aeration systems is the low capital cost of surface based or floating oxygen aerators compared to the conventional air-based submerged diffusers.

[0026] Finally, the installation and repair of surface based oxygen aerators such as the Praxair supplied I-SOTM unit is much simpler and generally less costly than installation, maintenance and repair of many submerged diffusers. For example, the installation of the surface based oxygen aerators are accomplished by mechanically lowering the unit into a full aeration tank. Scheduled maintenance usually consists of an annual oil change, which can be performed while standing on the float for the surface based aeration unit. Based on operating history, mechanical repairs to the surface based aerator, such as replacement of the impeller or gear box are projected to be required every 4 years or less often. In contrast, the costs associated with installation, maintenance and repair of submerged diffusers is somewhat higher as the aeration tank must typically be emptied prior to conducting such installation, scheduled maintenance or mechanical repairs.

[0027] An important aspect of the presents system and method for ozone vent gas reuse is the ability to control the flow of the ozone vent gas stream so as to optimize the aeration process using ozone vent gas. An effective gas reuse control system can overcome some of the challenges and problems typically associated with ozone related gas reuse. For example, a common problem encountered when considering ozone vent gas reuse for aeration purposes is that there is insufficient oxygen content or purity in the ozone vent gas stream to meet the targeted aeration process requirements. Oxygen concentration in the vent gas

affects both the quantity of oxygen provided (concentration times gas volumetric flow) and the efficiency of the aeration device (since the higher the concentration of oxygen, the less energy needed to dissolve a given mass of oxygen.) A control scheme suitable to ensure the oxygen content in the ozone vent gas flow is sufficient to meet the aeration requirements (from both quantity and efficiency perspectives) is to incorporate an online oxygen gas purity measuring system to estimate the real time oxygen partial pressures in ozone vent gas stream. The estimated oxygen partial pressures can be used for a variety of control purposes - for example, to establish the required volumes, if any, of make-up oxygen to be added to the ozone vent gas stream to meet the aeration process needs, or to control the venting process from the ozone contacting system to maintain high vent gas purities.

[0028] Alternatively, a control scheme may be established that sets a minimum oxygen gas flow to the ozone production system that produces sufficient oxygen in the ozone vent gas required for the average influent flow to the aeration basin to be treated with the ozone vent gas. The production of ozone within this oxygen gas flow can be controlled by varying power input to the ozone generator, to meet the needs of the ozone treatment process (such as disinfection.) The control scheme can compensate for higher than average conditions by adding supplemental or make-up oxygen gas to the ozone vent gas stream. Alternatively, higher or lower aeration needs for oxygen can be met, within constraints of oxygen flow in the ozone contactor, by varying the oxygen gas flow rate to the ozone generator, and adjusting ozone generator power as required to maintain desired ozone reaction. For example, using a liquid phase ozone sensor and implement a control loop to maintain a desired ozone level by varying power input to ozone generator. The desired ozone level and corresponding oxygen level in the ozone vent gas stream could be a feedback control loop, with a feed-forward control based on influent flow into the aeration basin.

[0029] Another problem or design challenge associated with ozone vent gas reuse is that the ozone vent gas entrains excess air, reducing the oxygen content and oxygen purity level. This is usually caused by either low pressure conditions in

the headspace of ozone contacting tank which typically causes breather valves on the ozone contacting tank to open and introduce excess air into the headspace and reducing oxygen purity levels in the ozone vent gas stream; or excess nitrogen gas stripping occurring in the ozone contactor.

[0030] To solve the low pressure problem, the present system and method contemplates coupling a source of oxygen gas to the ozone collection tank via pressure correction valves and introducing oxygen gas to the ozone collection tank in lieu of air in such low pressure situations. Alternatively, the oxygen flow rate to the ozone generator and ozone contacting system can be varied to maintain a slight positive pressure in the contacting system, while ozone production is controlled separately through control of ozone generator power.

[0031] A more elegant solution to both problems employs a control scheme that (i) varies the speed of a variable speed vent gas blower in the discharge line to avoid low pressure conditions in the ozone contactor tank and minimize air infiltration; (ii) vary the oxygen flow to the ozone generator to maintain the oxygen purity level in the headspace of the ozone contactor tank and ozone vent gas stream; (iii) vary the power to ozone generator to maintain the appropriate ozone residual in contactor tank. To effect these control schemes, inputs to the controller would presumably include ozone sensors, oxygen sensors and/or pressure sensors in the headspace of the ozone contactor tank or ozone vent gas conduits. Controlling the variable speed vent gas blower allows the operator to maintain a slight positive pressure in the headspace of the ozone contactor tank, or it can be controlled to maintain oxygen purity in the vent gas within a certain range.

[0032] A still more interesting solution to address both problems is to use a side stream ozone contactor in lieu of typical ozone contactor tank with fine bubble diffusers. The side stream ozone contactor enhances ozone dissolution as well as to introduce any required supplemental oxygen gas flows. Using this side stream contactor approach, it is possible to minimize post side stream contacting gas dissolution by minimizing contact time and rapidly expanding pipe dimensions post side stream contacting to facilitate phase separation and minimize oxygen

dissolution. The side stream embodiment minimizes the air entrainment issue as it is a closed, pressurized system and allows for use of a gas/liquid separator at positive pressure to remove the vent gas. It also treats only part of the liquid flow, supersaturating it, so we only strip nitrogen from part of the flow into the vent gas. This greatly decreases the amount of nitrogen in the vent gas.

[0033] Any control scheme that varies the percent ozone produced by the ozone generator will alter the content and volume of the ozone vent gas and the control thereof allows one to balance the loads between need for ozone in the tertiary treatment and needs for oxygen gas via the ozone vent gas stream. Such a control scheme allows essentially, independent control of oxygen gas flow through the ozone generator and ozone generator power.

[0034] In the preferred embodiments, the low-pressure ozone vent gas stream is dissolved in the aerobic section of the wastewater treatment plant using a plurality of Praxair's I-SO™ aeration systems which are able to induce gas flows from the ozone vent gas stream using a high strength vortex generated by the rotational action of a helical impeller within a draft tube. The I-SO™ system's capacity for ozone vent gas induction eliminates the need for the compression of the ozone vent gas stream and associated compression costs.

[0035] Using the I-SO™ surface based aeration system and one or more of the above-identified control schemes, the ozone vent gas is almost entirely recovered from the closed-tank ozone contactor system, as long as optimum pressure in the ozone contactor tank headspace is maintained. In effect, the number of aeration units and operating conditions (i.e. rotational speed of the impellers) of such aeration units receiving the ozone vent gas stream are used to maintain appropriate pressure in the headspace of the ozone contactor tank, which limits both air intrusion when pressure in the headspace of the contactor tank is too low, and direct ventilation or wasting of the ozone vent gas to the atmosphere when the pressure in the headspace of the contactor tank is too high.

[0036] Turning now to Fig. 2, there is shown a schematic illustration of another embodiment of the present system and method for ozone related gas reuse in a wastewater treatment system. Similar to the embodiment of Fig. 1, the wastewater

treatment system 10 includes an intake conduit 14 adapted to direct an influent 13 of wastewater to an aerobic section 20 of the wastewater treatment system 10. The illustrated system also includes one or more clarifiers 22 downstream of the aerobic section 20 adapted to separate at least some liquid effluent from a sludge flow, an output conduit 24 for transporting the liquid effluent 23; a waste activated sludge (WAS) line 26; and a return activated sludge (RAS) line 28 adapted to transport and return a portion of the separated sludge stream back to the aerobic section 20 via intake conduit 14.

[0037] Within the RAS line 28, there is a sludge ozonation system 70 that includes a pump 72 to direct the RAS sludge to a plug flow type ozonation reactor. The plug flow type ozonation reactor includes a sufficient length of pipe 78 that assures a residence time of the sludge in the ozonation reactor that is adequate for ensuring effective dissolution of the ozone and reaction of the ozone with the biosolids in the RAS line 28. The illustrated embodiments also include one or more ozone gas injection systems comprising a source of oxygen gas 32, an ozone generator 74 for producing an ozone-enriched gas and one or more nozzles or venturi type devices 76 for injecting the ozone-enriched gas into the ozonation reactor through which the RAS sludge passes.

[0038] Upon exiting the plug-flow type ozonation reactor, the ozonated sludge is then directed to a degassing unit 60 or gas-liquid separator to remove the excess oxygen containing gas. The excess oxygen containing gas 66 is then directed via a supplemental oxygen delivery conduit coupling the stream to one or more aeration/oxygenation units 50 where it is used to oxygenate the contents 44 of the aerobic section 20 of the wastewater treatment system 10 for reuse in the aeration process. The degassed ozonated sludge 62 is returned to the aerobic section 20 via intake conduit 14.

[0039] As with the earlier described embodiment, the disclosed system and process also employs a microprocessor based control unit operatively coupled to the ozone generator 74, the one or more aeration/oxygenation units 50, the oxygen feed stream 32 and a plurality of sensors (not shown) characterizing the gas contents (e.g. oxygen content, nitrogen content, carbon dioxide content, ozone

content, etc.), pressures, and/or temperatures within the degassing unit 60, the oxygen containing discharge stream 66, and the aerobic section 20 of the wastewater treatment system 10.

[0040] As an example of the ozone vent gas reuse approach was embodied in an expansion section of a municipal wastewater treatment plant. The expansion section was designed to utilize the ozone vent gas from an ozone contactor as a source of oxygen for aeration in the secondary anoxic-anaerobic-oxic (AAO) process. The expansion of the wastewater treatment plant increased the capacity of the plant from about 120,000 m³/day to about 150,000 m³/day. The oxygen requirements for the incremental flow (30,000 m³/day) in the expansion section was met completely by using the ozone vent gas from a tertiary treatment ozonation system applied to the entire effluent flow from the plant.

[0041] The oxygen source is liquid oxygen, which is vaporized at a rate of approximately 16.5 mtpd. The vaporized oxygen is then mixed with 0.5 mtpd of oxygen gas from bleed air (which contains about 78% nitrogen gas), to provide nitrogen in the ozone generator feed gas. It has been found that a nitrogen content of about 1% to 5% in the feed gas, leads to higher power efficiency for the ozone generation. The 17 mtpd oxygen in the feed gas is used by an ozone generator to make an ozone stream gas, which is roughly 9% ozone by weight. This ozone gas is then fed into submerged diffusers in four ozone-contacting tanks to maintain a concentration of 5 mg ozone/liter in the ozone contacting tanks. In the ozone contacting tanks, it is estimated that about 7 mtpd oxygen are lost through a combination of ozone reaction, increase in dissolved oxygen in the effluent and losses through the contactor. The remaining 10 mtpd of oxygen gas is available for aeration or other purposes. The oxygen-rich ozone vent gas stream (i.e. about 75-85% pure oxygen) is reused and applied to an aeration zone in the expansion section of the municipal wastewater treatment plant, specifically in the reverse AAO process designed for nitrogen and phosphorus biological nutrient removal.

[0042] The capital and operating cost savings associated with the usage of ozone vent gas for aeration compared to air based aeration of the 30,000 m³/day expansion section are projected to be about 56% for capital with approximately

the same relative savings for operating costs related to aeration in the plant expansion. Another advantage of the ozone vent gas reuse based aeration system is that it uses floating aerators, so it is not necessary to drain the aeration basin for aerator maintenance.

[0043] While the inventions herein disclosed have been described by means of specific embodiments and processes associated therewith, numerous modifications and variations can be made thereto by those skilled in the art. For example, the ozone vent gas stream may be directed to primary influent stream to raise the dissolved oxygen level for odor control or to supplement existing air-based aeration systems and/or existing high purity oxygen based aeration systems in the wastewater treatment plant. Still further, an ozone vent gas recovery process in a wastewater treatment plant could be coupled to enhance other unit operations, such as upstream anaerobic treatments, membrane bioreactors, fixed film systems, sequencing batch reactors, etc.

Claims

1. A method for supplying supplemental oxygen to a wastewater treatment system comprising the steps of:
 - directing an oxygen containing feed stream to an ozone generator;
 - operating the ozone generator to produce an ozone containing gas stream;
 - directing the ozone containing gas stream to an ozone treatment system within the wastewater treatment system to produce an ozone treated effluent and ;
 - and an ozone vent gas stream; and
 - directing the ozone vent gas stream to a mechanically agitating contactor in an aerobic section of the wastewater treatment system;
 - wherein the oxygen content of the ozone vent gas stream is controlled so as to ensure sufficient oxygenation to the aerobic section of the wastewater treatment system by adjusting the oxygen content of the ozone vent gas stream in response to sensor or measurement inputs characterizing the gas contents of the ozone vent gas stream or the dissolved oxygen level in the aerobic section of the wastewater treatment section.
2. The method of claim 1 further comprising the step of directing the ozone vent gas stream to an ozone destruct system configured to destroy any ozone contained in the ozone vent gas stream.
3. The method of claim 1 wherein the step of directing the ozone vent gas stream to the aerobic section of the wastewater treatment system further comprises mixing or combining the ozone vent gas stream with a make-up oxygen containing stream and directing the combined stream to the aerobic section of the wastewater treatment system.
4. The method of claim 1 wherein the step of adjusting the oxygen content of the ozone vent gas stream further comprises adjusting the flow of the oxygen containing feed stream to the ozone generator.

5. The method of claim 1 wherein the step of adjusting the oxygen content of the ozone vent gas stream further comprises adjusting the power supplied to the ozone generator.
6. The method of claim 1 wherein the step of adjusting the oxygen content of the ozone vent gas stream further comprises adjusting the flow of a make-up oxygen containing stream to the ozone vent gas stream.
7. The method of claim 1 wherein the volumetric flow of the ozone vent gas stream is controlled so as to ensure sufficient oxygenation to the aerobic section of the wastewater treatment system by adjusting the rotational speed of the mechanically agitating contactor in an aerobic section of the wastewater treatment system.
8. A ozone vent gas reuse system for a wastewater treatment plant comprising:
 - an oxygen containing feed stream;
 - an ozone generator configured to receive the oxygen containing feed stream and produce an ozone containing gas stream
 - an ozone contactor for contacting an effluent with the ozone containing gas stream to produce an ozone treated effluent and an ozone vent gas stream;
 - an ozone destruct system configured to receive the ozone vent gas stream and destroy any ozone contained in the ozone vent gas stream;
 - a supplemental oxygen delivery conduit coupling the ozone vent gas stream to a mechanically agitating contactor in an aerobic section of the wastewater treatment plant; and
 - a control unit for controlling the oxygen content of the ozone vent gas stream so as to ensure sufficient oxygenation to the aerobic section of the wastewater treatment system by adjusting the oxygen content of the ozone vent gas stream in response to sensor or measurement inputs characterizing the gas contents of the ozone vent gas stream or the dissolved oxygen level in the aerobic section of the wastewater treatment section.

9. The system of claim 8 wherein the ozone vent gas stream is mixed or combined with a make-up oxygen containing stream and directing the combined stream to the aeration basin of the wastewater treatment system.
and the combined stream is directed to the aeration basin of the wastewater treatment plant.
10. The system of claim 8 wherein the control unit adjusts the oxygen content of the ozone vent gas stream by adjusting the flow of the oxygen containing feed stream to the ozone generator.
11. The system of claim 8 wherein the control unit adjusts the oxygen content of the ozone vent gas stream by adjusting the power supplied to the ozone generator.
12. The system of claim 8 wherein the control unit adjusts the oxygen content of the ozone vent gas stream by adjusting the flow of a make-up oxygen containing stream to the ozone vent gas stream.
13. The system of claim 8 wherein the control unit further controls the volumetric flow of the ozone vent gas stream by adjusting the rotational speed of the mechanically agitating contactor in an aerobic section of the wastewater treatment system so as to ensure sufficient oxygenation to the aerobic section of the wastewater treatment system.

14. A method for supplying supplemental oxygen in a wastewater treatment system comprising the steps of:
- directing an oxygen or ozone containing sludge stream within the wastewater treatment system to a degassing unit;
 - separating an oxygen containing off-gas from the sludge stream to produce a supplemental oxygen containing gas stream; and
 - directing the supplemental oxygen containing gas stream to an aerobic, anaerobic or anoxic section of the wastewater treatment system
- wherein the oxygen content of the supplemental oxygen containing gas stream is controlled in response to sensor or measurement inputs characterizing the gas contents of the ozone vent gas stream.
15. The method of claim 14 wherein the step of directing the supplemental oxygen containing gas stream further comprises mixing or combining the supplemental oxygen containing gas stream with a make-up oxygen containing stream and directing the combined stream to the aerobic, anaerobic or anoxic section of the wastewater treatment system.
16. The method of claim 14 wherein the step of directing the supplemental oxygen containing gas stream further comprises directing the supplemental oxygen containing gas stream to a mechanically agitating contactor in the aerobic, anaerobic or anoxic section of the wastewater treatment system, the mechanically agitating contactor configured to assist or enhance in the dissolution of oxygen from the supplemental oxygen containing stream into the contents of the aerobic, anaerobic or anoxic section of the wastewater treatment system.
17. The method of claim 14 wherein the step of directing the supplemental oxygen containing gas stream further comprises directing the supplemental oxygen containing stream to a digester for micro-oxygenation of the contents of the digester.

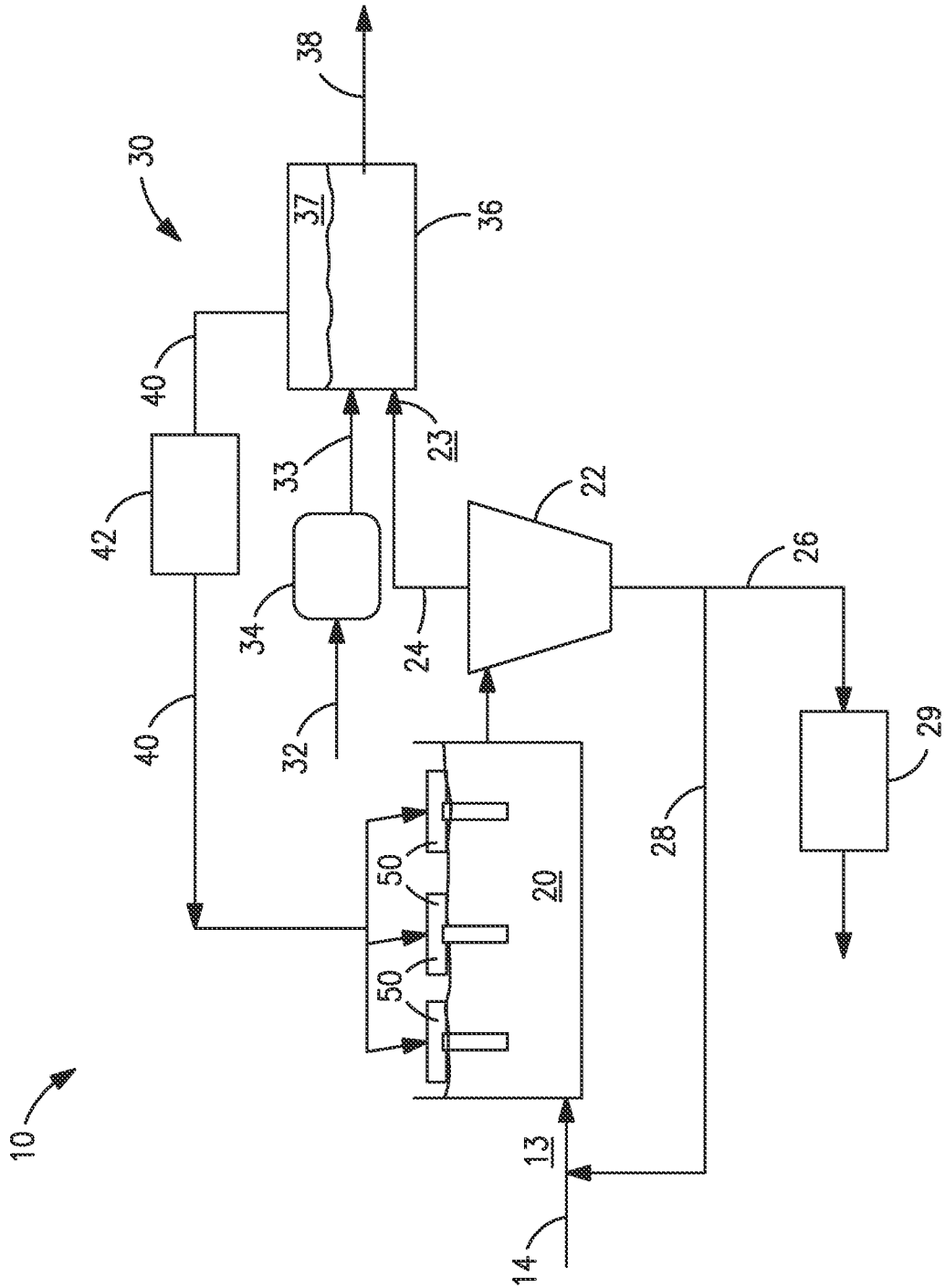


FIG. 1

