suppression of NOB is not feasible. In this context, we define the term out-selection as an approach to repress NOBs through the achievement of higher rates for AOBs, thus producing nitrite for other organisms.

SUMMARY

[0011] In one aspect, the present disclosure refers to a wastewater treatment apparatus, comprising: a biological nitrogen removal (BNR) reactor having a volume that is transiently aerated; an ammonia sensor in the BNR reactor and directly measuring an ammonia concentration signal; a dissolved oxygen (DO) sensor in the BNR reactor; and a controller for processing the ammonia concentration signal and thereby limiting a growth of nitrite oxidizing bacteria (NOB) under controlled aeration conditions, the conditions being controlled either along the flow-path or along the process time-line, and wherein the wastewater treatment apparatus has an aeration system activation interval, an upper DO setpoint for the BNR reactor, or both, and wherein the wastewater treatment apparatus is configured to set the aeration system activation interval, the upper DO setpoint, or both are set such that a measured ammonia concentration is higher than 1.5 mg/L ammonia as nitrogen, for more than 75% of the reactor volume in space or time, wherein the wastewater treatment apparatus switches between a lower DO setpoint of less than 0.1 mg/L of dissolved oxygen and the upper DO setpoint of greater than 1.0 mg/L of dissolved oxygen.

[0011a] In another aspect, the present disclosure refers to a wastewater treatment apparatus, comprising: a biological nitrogen removal (BNR) reactor having a volume that is transiently aerated; an ammonia sensor in the BNR reactor and directly measuring an ammonia concentration signal; a dissolved oxygen (DO) sensor in the BNR reactor; and a controller for processing the ammonia concentration signal and thereby limiting a growth of nitrite oxidizing bacteria (NOB) under controlled aeration conditions, the conditions being controlled either along the flow-path or along the process time-line, and wherein the aeration system activation interval, an upper DO setpoint for the BNR reactor, or both are set such that a measured ammonia concentration is higher than 1.5 mg/L ammonia as nitrogen, for more than 75% of the reactor volume in space or time, and wherein the wastewater treatment apparatus further includes a high-ammonia-strength reactor for bioaugmentation of anammox organisms to provide microbial competitors for nitrite to limit the growth of NOB, wherein the wastewater treatment apparatus switches between a lower DO setpoint of less than 0.1 mg/L of dissolved oxygen and the upper DO setpoint of greater than 1.0 mg/L of dissolved oxygen.

[0011b] In another aspect, the present disclosure refers to a wastewater treatment method, comprising: providing a biological nitrogen removal (BNR) reactor that is transiently aerated; using an ammonia sensor in the BNR reactor and directly measuring an ammonia concentration signal; measuring dissolved oxygen (DO) using a DO sensor located in the BNR reactor; using a controller to process the ammonia concentration signal and

thereby limiting a growth of nitrite oxidizing bacteria (NOB) under aeration conditions, the conditions being controlled either along the flow-path or along the process time-line; and setting the aeration system activation interval, an upper dissolved oxygen (DO) setpoint for the BNR reactor, or both such that a measured ammonia concentration is higher than 1.5 mg/L ammonia as nitrogen, for more than 75% of the reactor volume in space or time; and switching between a lower DO setpoint of less than 0.1 mg/L of dissolved oxygen and the upper DO setpoint of greater than 1.0 mg/L of dissolved oxygen.

[0011c] The present disclosure achieves a proper and measured control of maintaining high AOB oxidation rates while achieving NOB out-selection, using various control strategies, including: 1) aeration control ensuring nearly saturated ammonia concentration and DO profiles varying from a high set-point rapidly depleting close to zero for maximized AOB-rates during aerobic phases; 2) an innovative aeration control strategy based on the ratio of on-line measured NH_4- and NOx signals in order to maximize total nitrogen removal and to provide an optimum stoichiometric substrate ratio for the anammox reaction; 3) aggressive aerobic SRT management for wash-out pressure on NOB; and 4) bioaugmentation of anammox and lighter flocculant AOB fraction. The use of such control strategies provides important advantages over prior art strategies.

[0012] Accordingly, the present disclosure describes a system and method of removing nitrogen from wastewater in a reactor for biological nitrogen removal, wherein an aerobic-anoxic duration and/or a concentration of dissolved oxygen in the reactor is controlled based on a ratio of an ammonia concentration to a concentration of oxidized nitrogen (NOx, sum of nitrite and nitrate concentrations) measured in real time. Typically, the aerobic-anoxic duration and/or the concentration of dissolved oxygen in the reactor is controlled to achieve a ratio of ammonia concentration to a concentration of oxidized nitrogen that is within a range of 0.5 to 1.5, preferably between 0.7 to 1.0. By employing the system and method of the present disclosure, overall nitrogen removal is maximized because denitrification (dependent on chemical oxygen demand (COD) input) and subsequent ammonia oxidation balance each other while also favoring AOB over NOB. Alternatively, instead of applying a ratio, the difference between ammonia concentration and concentration of oxidized nitrogen can be controlled to a value near 0 which leads to an equivalent control performance.

CLAIMS

1. A wastewater treatment apparatus, comprising:

a biological nitrogen removal (BNR) reactor having a volume that is transiently aerated;

an ammonia sensor in the BNR reactor and directly measuring an ammonia concentration signal;

a dissolved oxygen (DO) sensor in the BNR reactor; and

a controller for processing the ammonia concentration signal and thereby limiting a growth of nitrite oxidizing bacteria (NOB) under controlled aeration conditions, the conditions being controlled either along the flow-path or along the process time-line, and

wherein the wastewater treatment apparatus has an aeration system activation interval, an upper DO setpoint for the BNR reactor, or both, and wherein the wastewater treatment apparatus sets the aeration system activation interval, the upper DO setpoint, or both are set such that a measured ammonia concentration is higher than 1.5 mg/L ammonia as nitrogen, for more than 75% of the reactor volume in space or time, wherein the wastewater treatment apparatus switches between a lower DO setpoint of less than 0.1 mg/L of dissolved oxygen and the upper DO setpoint of greater than 1.0 mg/L of dissolved oxygen.

2. The apparatus of claim 1, further comprising an oxidized nitrogen sensor for sensing oxidized nitrogen in the reactor, and for generating concentration signals for nitrite, nitrate, or combination of nitrite and nitrate and wherein the controller processes the ammonia and oxidized nitrogen concentration signals, and controls DO concentration, duration of an aerobic period, and/or duration of an anoxic period, in the reactor, based on the ammonia concentration and an oxidized nitrogen concentration.

3. The apparatus of claim 2, wherein the controller generates instructions for increasing, decreasing or maintaining the DO concentration, the duration of the aerobic period, and/or the duration of the anoxic period in the reactor based on a ratio or sum of the ammonia concentration and oxidized nitrogen concentration and/or including a defined offset ammonia concentration.

4. The apparatus of claim 1, wherein the BNR reactor receives bioaugmentation of ammonia oxidizing bacteria (AOB) from a high-ammonia-strength reactor, having a reactor feed concentration greater than 200 mg/L ammonia as nitrogen, and wherein a less dense, more compressible, or unattached sludge fraction is selected from the high-ammonia-strength reactor for the bioaugmentation, and fed to the BNR reactor such that retention time of the bioaugmentation fraction is less than 10 days in the high-ammonia-strength reactor.

5. The apparatus of claim 1, wherein anoxic conditions supporting anaerobic ammonia oxidizing bacteria are promoted in space in the reactor using a biofilm or granular zone within a geometry of the reactor or in time in the reactor with a floc, biofilm, or granule.

6. A wastewater treatment apparatus, comprising:
a biological nitrogen removal (BNR) reactor having a volume that is transiently aerated;
an ammonia sensor in the BNR reactor and directly measuring an ammonia concentration signal;
a dissolved oxygen (DO) sensor in the BNR reactor; and
a controller for processing the ammonia concentration signal and thereby limiting a growth of nitrite oxidizing bacteria (NOB) under controlled aeration conditions, the conditions being controlled either along the flow-path or along the process time-line, and
wherein the aeration system activation interval, an upper DO setpoint for the BNR reactor, or both are set such that a measured ammonia concentration is higher than 1.5 mg/L ammonia as nitrogen, for more than 75% of the reactor volume in space or time, and
wherein the wastewater treatment apparatus further includes a high-ammonia-strength reactor for bioaugmentation of anammox organisms to provide microbial competitors for nitrite to limit the growth of NOB, wherein the wastewater treatment apparatus switches between a lower DO setpoint of less than 0.1 mg/L of dissolved oxygen and the upper DO setpoint of greater than 1.0 mg/L of dissolved oxygen.

7. A wastewater treatment method, comprising:

providing a biological nitrogen removal (BNR) reactor that is transiently aerated;

using an ammonia sensor in the BNR reactor and directly measuring an ammonia concentration signal;

measuring dissolved oxygen (DO) using a DO sensor located in the BNR reactor;

using a controller to process the ammonia concentration signal and thereby limiting a growth of nitrite oxidizing bacteria (NOB) under aeration conditions, the conditions being controlled either along the flow-path or along the process time-line;

setting the aeration system activation interval, an upper dissolved oxygen (DO) setpoint for the BNR reactor, or both such that a measured ammonia concentration is higher than 1.5 mg/L ammonia as nitrogen, for more than 75% of the reactor volume in space or time; and

switching between a lower DO setpoint of less than 0.1 mg/L of dissolved oxygen and the upper DO setpoint of greater than 1.0 mg/L of dissolved oxygen.

8. The method of claim 7, further comprising decreasing an NOB net observed growth rate by exposure to an inhibitor, a nitrogenous metabolic intermediate, or a toxic substance.

9. The method of claim 7, further comprising using a growth factor to increase ammonia oxidizing bacteria (AOB) and anammox net growth rates.

10. The method of claim 7, further comprising the step of feeding ammonia oxidizing bacteria (AOB) to the BNR reactor from a high-ammonia-strength reactor, having a reactor feed concentration greater than 200 mg/L ammonia as nitrogen, and wherein a less dense, more compressible, or unattached sludge fraction is selected from the high-ammonia-strength reactor, and is fed to the BNR reactor such that retention time of the fraction is less than 10 days in the high-ammonia-strength reactor.

11. The method of claim 7, further comprising the step of providing a high-ammonia-strength reactor for bioaugmentation of anammox organisms, and using the high-ammonia-strength reactor to provide microbial competitors for nitrite to limit the growth of NOB.

12. The method of claim 7, further comprising promoting in space anoxic conditions in the reactor using a biofilm or granular zone within a geometry of the reactor or in time anoxic conditions in the reactor with a floc, biofilm, or granule.