SUMMARY

[009] Accordingly, the instant 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 [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 [sum of nitrite and nitrate concentrations] that is about 1. Alternatively, the aerobic-anoxic duration and/or the concentration of dissolved oxygen in the reactor may be controlled to achieve a predetermined ratio of [ammonia concentration] to a [sum of nitrite and nitrate concentrations] that is less than or greater than 1. By employing the system and method of the instant disclosure, overall nitrogen removal is maximized because denitrification (dependent on COD input) and subsequent ammonia oxidation balance each other while also favoring AOB over NOB.

[0010] The system and method of the disclosure can be used to achieve a proper and measured control of a mainstream SND process that maximizes TIN removal through one of several nitrogen removal mechanisms including, nitrification-denitrification, nitritation-denitritation (scBNR), partial nitritation-denitritation producing an effluent stream appropriate for polishing by anammox in a separate downstream reactor, and partial nitritation-anammox in a single tank with selective anammox retention. These systems and methods use various control strategies, including: 1) real time measurement of ammonia, nitrite and nitrate, 2) operational DO and the proper use of DO setpoints controlled based on a ratio of the ammonia concentration to the nitrite + nitrate concentration measured in the reactor, 3) control of a frequency of aeration based on a ratio of the ammonia concentration to the nitrite + nitrate concentration measured in the reactor, and 4) proper implementation of transient anoxia within a wide range of apparatus (reactor configurations) and operating conditions. In one aspect, the present invention refers to a system for removing nitrogen from a reactor for biological nitrogen removal from wastewaters comprising: a) a reactor; b) an ammonia sensor that senses a concentration of ammonia in the reactor in real time and generates an ammonia concentration signal; c) a nitrite sensor that senses a concentration of nitrite in the reactor in real time and generates a nitrite concentration signal; d) a nitrate sensor that senses a concentration of nitrate in the reactor in real time and generates a nitrate concentration signal; e) a controller that receives the ammonia concentration signal, nitrite concentration signal and nitrate concentration signal and generates instructions for increasing, decreasing

or maintaining a concentration of dissolved oxygen in the reactor based on a ratio of the [concentration of ammonia] to [a sum of the concentrations of nitrite and nitrate]; f) a dissolved oxygen modulator that supplies dissolved oxygen to the reactor under control of the controller based on the ratio of the [concentration of ammonia] to [the sum of the concentrations of nitrite and nitrate], wherein the system is configured to provide nitrite oxidizing bacteria repression and the production of an effluent stream for post-anammox polishing; and g) a plurality of anammox organisms in a post-anammox polishing reactor.

In another aspect, the present invention refers to a system for removing nitrogen from a reactor for biological nitrogen removal from wastewaters comprising: a) a reactor; b) an ammonia sensor that senses a concentration of ammonia in the reactor in real time and generates an ammonia concentration signal; c) a nitrite sensor that senses a concentration of nitrite in the reactor in real time and generates a nitrite concentration signal; d) a nitrate sensor that senses a concentration of nitrate in the reactor in real time and generates a nitrate concentration signal; e) a controller that receives the ammonia concentration signal, nitrite concentration signal and nitrate concentration signal and generates instructions for increasing, decreasing or maintaining a duration of aerobic and anoxic period within the reactor based on a ratio of the [concentration of ammonia] to [a sum of the concentrations of nitrite and nitrate]; f) a dissolved oxygen modulator that supplies the dissolved oxygen to the reactor to control the duration of aerobic and anoxic periods, wherein the dissolved oxygen modulator is under the control of the controller and controls the duration of the aerobic and anoxic periods based on the ratio of the [concentration of ammonia] to [the sum of the concentrations of nitrite and nitrate]; and g) a plurality of anammox organisms that provides nitrite oxidizing bacteria repression, wherein the system is configured to produce an effluent stream, wherein said effluent stream is produced such that anammox process bacteria can be selectively retained. In another aspect, the present invention refers to a system for removing nitrogen from a reactor for biological nitrogen removal from wastewaters comprising: a) a reactor; b) an ammonia sensor that senses a concentration of ammonia in the reactor in real time and generates an ammonia concentration signal; c) a nitrite sensor that senses a concentration of nitrite in the reactor in real time and generates a nitrite concentration signal; d) a nitrate sensor that senses a concentration of nitrate in the reactor in real time and generates a nitrate concentration signal; e) a controller that receives the ammonia concentration signal, nitrite concentration signal and nitrate concentration signal and generates instructions for increasing, decreasing or maintaining a concentration of dissolved oxygen in the reactor based on a ratio of the [concentration of ammonia] to [a sum of the concentrations of nitrite and nitrate]; f) a dissolved oxygen

modulator that supplies dissolved oxygen to the reactor under control of the controller based on the ratio of the [concentration of ammonia] to [the sum of the concentrations of nitrite and nitrate], and g) a plurality of anammox organisms that provides nitrite oxidizing bacteria repression, wherein the system is configured to produce an effluent stream, wherein said effluent stream is produced such that anammox bacteria can be selectively retained. In another aspect, the present invention refers to a system for removing nitrogen from a reactor for biological nitrogen removal from wastewaters comprising: a) a reactor; b) an ammonia sensor that senses a concentration of ammonia in the reactor in real time and generates an ammonia concentration signal; c) a nitrite sensor that senses a concentration of nitrite in the reactor in real time and generates a nitrite concentration signal; d) a nitrate sensor that senses a concentration of nitrate in the reactor in real time and generates a nitrate concentration signal; e) a controller that receives the ammonia concentration signal, nitrite concentration signal and nitrate concentration signal and generates instructions for increasing, decreasing or maintaining a duration of aerobic and anoxic period within the reactor based on a ratio of the [concentration of ammonia] to [a sum of the concentrations of nitrite and nitrate]; f) a dissolved oxygen modulator that supplies the dissolved oxygen to the reactor to control the duration of aerobic and anoxic pericids, wherein the dissolved oxygen modulator is under the control of the controller and controls the duration of the aerobic and anoxic periods based on the ratio of the [concentration of ammonia] to [the sum of the concentrations of nitrite and nitrate], wherein the system is configured to provide nitrite oxidizing bacteria repression and the production of an effluent stream for post-anammox polishing; and g) a plurality of anammox organisms in a post-anammox polishing reactor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. 1 is a molar flowchart showing the reactions associated with conventional nitrification and denitrification.

[0012] FIG. 2 is a molar flowchart showing the reactions associated with

CLAIMS

1. A system for removing nitrogen from a reactor for biological nitrogen removal from wastewaters comprising:

a) a reactor;

b) an ammonia sensor that senses a concentration of ammonia in the reactor in real time and generates an ammonia concentration signal;

c) a nitrite sensor that senses a concentration of nitrite in the reactor in real time and generates a nitrite concentration signal;

d) a nitrate sensor that senses a concentration of nitrate in the reactor in real time and generates a nitrate concentration signal;

e) a controller that receives the ammonia concentration signal, nitrite concentration signal and nitrate concentration signal and generates instructions for increasing, decreasing or maintaining a concentration of dissolved oxygen in the reactor based on a ratio of the [concentration of ammonia] to [a sum of the concentrations of nitrite and nitrate];

f) a dissolved oxygen modulator that supplies dissolved oxygen to the reactor under control of the controller based on the ratio of the [concentration of ammonia] to [the sum of the concentrations of nitrite and nitrate], wherein the system is configured to provide nitrite oxidizing bacteria repression and the production of an effluent stream for post-anammox polishing; and

g) a plurality of anammox organisms in a post-anammox polishing reactor.

2. The system of claim 1, wherein the controller generates instructions for increasing the concentration of dissolved oxygen if the ratio of the [concentration of ammonia] to [the sum of the concentrations of nitrite and nitrate] is greater than 1.

3. The system of claim 1, wherein the controller generates instructions for decreasing the concentration of dissolved oxygen if the ratio of the [concentration of ammonia] to [the sum of the concentrations of nitrite and nitrate] is less than 1.

4. The system of claim 1, wherein the controller generates instructions for maintaining the

concentration of dissolved oxygen if the ratio of the [concentration of ammonia] to [the sum of the concentrations of nitrite and nitrate] is 1.

5. The system of claim 1, wherein the controller generates instructions for increasing or decreasing or maintaining the concentration of dissolved oxygen to maintain a ratio of [a sum of the concentrations of nitrite and nitrate] to a [concentration of ammonia] that is from about 1.18 to about 1.45.

6. The system of claim 5, wherein the controller generates instructions for increasing or decreasing or maintaining the concentration of dissolved oxygen to maintain the ratio of [the sum of the concentrations of nitrite and nitrate] to the [concentration of ammonia] that is equal to about 1.32.

7. A system for removing nitrogen from a reactor for biological nitrogen removal from wastewaters comprising:
a) a reactor;
b) an ammonia sensor that senses a concentration of ammonia in the reactor in real time and generates an ammonia concentration signal;
c) a nitrite sensor that senses a concentration of nitrite in the reactor in real time and generates a nitrite concentration signal;
d) a nitrate sensor that senses a concentration of nitrate in the reactor in real time and generates a nitrate concentration signal;
e) a controller that receives the ammonia concentration signal, nitrite concentration signal and nitrate concentration signal and generates instructions for increasing, decreasing or maintaining a duration of aerobic and anoxic period within the reactor based on a ratio of the [concentration of ammonia] to [a sum of the concentrations of nitrite and nitrate];
f) a dissolved oxygen modulator that supplies the dissolved oxygen to the reactor to control the duration of aerobic and anoxic periods, wherein the dissolved oxygen modulator is under the control of the controller and controls the duration of the aerobic and anoxic periods based on the ratio of the [concentration of ammonia] to [the sum of the concentrations of nitrite and nitrate]; and

g) a plurality of anammox organisms that provides nitrite oxidizing bacteria repression, wherein the system is configured to produce an effluent stream, wherein said effluent stream is produced such that anammox process bacteria can be selectively retained.

8. The system of claim 7, wherein the controller generates instructions for increasing the duration of the aerobic period and/or decreasing the duration of the anoxic period if the ratio of the [concentration of ammonia] to [the sum of the concentrations of nitrite and nitrate] is greater than 1.

9. The system of claim 7, wherein the controller generates instructions for decreasing the duration of the aerobic period and/or increasing the duration of the anoxic period if the ratio of the [concentration of ammonia] to [the sum of the concentrations of nitrite and nitrate] is less than 1.

10. The system of claim 7, wherein the controller generates instructions for maintaining the duration of the aerobic period and/or the duration of the anoxic period if the ratio of the [concentration of ammonia] to [the sum of the concentrations of nitrite and nitrate] is 1.

11. The apparatus of claim 1, further comprising a supply of acetate or acetic acid or other organic substrate that is added to accomplish denitratation (nitrate reduction to nitrite) and subsequent anammox growth on the provided ammonia and denitratation-produced nitrite.

12. The apparatus of claim 1, wherein the effluent stream contains approximately equal proportions of ammonia and nitrite on an as nitrogen basis, such that further nitrogen removal can be accomplished using anammox in a fully anoxic suspended or biofilm process.

13. A system for removing nitrogen from a reactor for biological nitrogen removal from wastewaters comprising:
a) a reactor;
b) an ammonia sensor that senses a concentration of ammonia in the reactor in real time and generates an ammonia concentration signal;

c) a nitrite sensor that senses a concentration of nitrite in the reactor in real time and generates a nitrite concentration signal;
d) a nitrate sensor that senses a concentration of nitrate in the reactor in real time and generates a nitrate concentration signal;
e) a controller that receives the ammonia concentration signal, nitrite concentration signal and nitrate concentration signal and generates instructions for increasing, decreasing or maintaining a concentration of dissolved oxygen in the reactor based on a ratio of the [concentration of ammonia] to [a sum of the concentrations of nitrite and nitrate];
f) a dissolved oxygen modulator that supplies dissolved oxygen to the reactor under control of the controller based on the ratio of the [concentration of ammonia] to [the sum of the concentrations of nitrite and nitrate], and
g) a plurality of anammox organisms that provides nitrite oxidizing bacteria repression, wherein the system is configured to produce an effluent stream, wherein said effluent stream is produced such that anammox bacteria can be selectively retained.

14. The system of claim 13, wherein the controller generates instructions for increasing the concentration of dissolved oxygen if the ratio of the [concentration of ammonia] to [the sum of the concentrations of nitrite and nitrate] is greater than 1.

15. The system of claim 13, wherein the controller generates instructions for decreasing the concentration of dissolved oxygen if the ratio of the [concentration of ammonia] to [the sum of the concentrations of nitrite and nitrate] is less than 1.

16. The system of claim 13, wherein the controller generates instructions for maintaining the concentration of dissolved oxygen if the ratio of the [concentration of ammonia] to [the sum of the concentrations of nitrite and nitrate] is 1.

17. The system of claim 13, wherein the controller generates instructions for increasing or decreasing or maintaining the concentration of dissolved oxygen to maintain a ratio of [a sum of the concentrations of nitrite and nitrate] to a [concentration of ammonia] that is from about 1.18 to about 1.45.

18. The system of claim 17, wherein the controller generates instructions for increasing or decreasing or maintaining the concentration of dissolved oxygen to maintain the ratio of [the sum of the concentrations of nitrite and nitrate] to the [concentration of ammonia] that is equal to about 1.32.

19. The apparatus of claim 13, wherein the effluent stream contains approximately equal proportions of ammonia and nitrite on an as nitrogen basis, such that further nitrogen removal can be accomplished using anammox in a fully anoxic suspended or biofilm process.

20. A system for removing nitrogen from a reactor for biological nitrogen removal from wastewaters comprising:

a) a reactor;

b) an ammonia sensor that senses a concentration of ammonia in the reactor in real time and generates an ammonia concentration signal;

c) a nitrite sensor that senses a concentration of nitrite in the reactor in real time and generates a nitrite concentration signal;

d) a nitrate sensor that senses a concentration of nitrate in the reactor in real time and generates a nitrate concentration signal;

e) a controller that receives the ammonia concentration signal, nitrite concentration signal and nitrate concentration signal and generates instructions for increasing, decreasing or maintaining a duration of aerobic and anoxic period within the reactor based on a ratio of the [concentration of ammonia] to [a sum of the concentrations of nitrite and nitrate];

f) a dissolved oxygen modulator that supplies the dissolved oxygen to the reactor to control the duration of aerobic and anoxic pericids, wherein the dissolved oxygen modulator is under the control of the controller and controls the duration of the aerobic and anoxic periods based on the ratio of the [concentration of ammonia] to [the sum of the concentrations of nitrite and nitrate], wherein the system is configured to provide nitrite oxidizing bacteria repression and the production of an effluent stream for post-anammox polishing; and

g) a plurality of anammox organisms in a post-anammox polishing reactor.

21. The apparatus of claim 20, further comprising a supply of acetate or acetic acid or other organic substrate that is added to accomplish denitratation (nitrate reduction to nitrite) and subsequent anammox growth on the provided ammonia and denitratation-produced nitrite.

22. The system of claim 20, wherein the controller generates instructions for increasing the duration of the aerobic period and/or decreasing the duration of the anoxic period if the ratio of the [concentration of ammonia] to [the sum of the concentrations of nitrite and nitrate] is greater than 1.

23. The system of claim 20, wherein the controller generates instructions for decreasing the duration of the aerobic period and/or increasing the duration of the anoxic period if the ratio of the [concentration of ammonia] to [the sum of the concentrations of nitrite and nitrate] is less than 1.

24. The system of claim 20, wherein the controller generates instructions for maintaining the duration of the aerobic period and/or the duration of the anoxic period if the ratio of the [concentration of ammonia] to [the sum of the concentrations of nitrite and nitrate] is 1.