METHOD AND APPARATUS FOR MAXIMIZING NITROGEN REMOVAL FROM WASTEWATER

Abstract: A reactor and control method for maximizing nitrogen removal and minimizing aeration requirements through control of transient anoxia and aerobic SRT, repression of NOB, and control of dynamic DO concentrations or aeration interval by keeping the reactor NH4 and NOx concentrations approximately equal. Controls are provided for maximizing the potential for TIN removal through nitrification, limited nitratation, denitrification, limited denitrification, denitrification making use of 1) real time measurement of ammonia, nitrite, nitrate, 2) operational DO and the proper use of DO setpoints, and 3) proper implementation of transient anoxia within a wide range of reactor configurations and operating conditions.
US, ZM, ZW), Eurasian (AM, AZ, BY, RO, KZ, RU, T)
TH, 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, SK, SI, SE,
SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ,
GW, KM, ML, MR, NE, SN, TD, TG).

Published:
— with international search report (Art. 21(3))
— with amended claims (Art. 19(1))

Date of publication of the amended claims: 13 November 2014
AMENDED CLAIMS

received by the International Bureau on 22 September 2014 (22.09.14)

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]; and
   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).

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]; and

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].

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) A method of removing nitrogen from wastewaters in a reactor comprising:
a) oxidizing a fraction of an influent ammonia load to produce nitrite and nitrate, wherein the oxidation is conducted by providing an amount of aeration that is sufficient to oxidize only a fraction of the influent ammonia for which there is a sufficient amount of chemical oxygen demand (COD) in the reactor that will subsequently reduce the oxidized nitrogen species;

b) measuring a concentration of ammonia, a concentration of nitrite and a concentration of nitrate in the reactor in real time; and

c) controlling a concentration of dissolved oxygen (DO) supplied to the reactor, and/or a frequency at which aeration occurs in the reactor, based on a ratio of the [concentration of ammonia] to a [sum of the concentrations of nitrite and nitrate].

12) The method of claim 11, wherein the concentration of dissolved oxygen supplied to the reactor and/or the frequency at which aeration occurs in the reactor is increased if the ratio of the [concentration of ammonia] to the [sum of the concentrations of nitrite and nitrate] is greater than 1.

13) The method of claim 11, wherein the concentration of dissolved oxygen supplied to the reactor and/or the frequency at which aeration occurs in the reactor is decreased if the ratio of the [concentration of ammonia] to the [sum of the concentrations of nitrite and nitrate] is less than 1.

14) The method of claim 11, wherein the concentration of dissolved oxygen supplied to the reactor and/or the frequency at which aeration occurs in the reactor is maintained if the ratio of the [concentration of ammonia] to the [sum of the concentrations of nitrite and nitrate] is 1.
15) The method of claim 11, further comprising controlling a limited aerobic sludge retention time in the reactor, wherein the limited aerobic sludge retention time is controlled based on a ratio of the [concentration of ammonia] to [a sum of the concentrations of nitrite and nitrate].

16) The method of claim 11, further comprising controlling an extension and/or volume of anoxic periods, wherein the extension and/or volume of anoxic periods is controlled based on a ratio of the [concentration of ammonia] to [a sum of the concentrations of nitrite and nitrate].

17) The method of claim 11, further comprising enhancing an oxygen uptake rate (OUR) to facilitate a plurality of rapid transitions from an aerobic condition to an anoxic condition by maintaining a concentration of a mixed liquor solid (MLSS) that is higher than 2 g/L or by maintaining equivalent biomass quantities in a biofilm system.

18) The method of claim 17, wherein an aeration control system is used to control a frequency of the transitions between the aerobic and anoxic conditions.

19) The method of claim 11, wherein the reactor is a sequencing batch reactor or a completely mixed reactor.

20) The method of claim 11, wherein the method is an oxidation ditch process or a plug flow process.

21) The method of claim 11, further comprising at least one of a suspended growth process, a granular process, a biofilm process or a combination thereof.

22) The method of claim 11, further comprising a separation process using a settler, a dissolved air flotation device, a filter or a membrane.
23) The method of claim 11, further comprising feeding a minimum mass-flow of organic carbon to the reactor to facilitate a rapid transition to an anoxic state from an aerated state and to provide additional competition for nitrite to improve repression of NOB.

24) The method of claim 11, further comprising supplying the reactor with an anammox organism to provide competition for nitrite to improve repression of NOB.

25) The apparatus of claim 1, wherein the apparatus is configured to provide conditions, with nitrite oxidizing bacteria repression and the production of an effluent stream containing 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, or to selectively retain anammox.

26) The apparatus of claim 25, wherein the apparatus is configured to provide conditions, with effluent stream containing a blend of ammonia, nitrite, and nitrate, such that further nitrogen removal can be accomplished using anammox in a fully anoxic suspended or biofilm process whereby acetate or acetic acid or other organic substrate are added to accomplish denitratation (nitrate reduction to nitrite) and subsequent anammox growth on the provided ammonia and denitratation-produced nitrite.

27) The method of claim 11, further comprising the step of providing conditions, with nitrite oxidizing bacteria repression and the production of an effluent stream containing 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.

28) The method of claim 27, further comprising the step of providing conditions, with an effluent stream containing a blend of ammonia, nitrite, and nitrate, such that further
nitrogen removal can be accomplished using anammox in a fully anoxic suspended or biofilm process whereby acetate or acetic acid or other organic substrate are added to accomplish denitratation (nitrate reduction to nitrite) and subsequent anammox growth on the provided ammonia and denitratation-produced nitrite.