



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : C02F 3/00, 3/12, 3/30	A1	(11) International Publication Number: WO 98/33745 (43) International Publication Date: 6 August 1998 (06.08.98)
(21) International Application Number: PCT/SE98/00120 (22) International Filing Date: 28 January 1998 (28.01.98) (30) Priority Data: 9700302-4 30 January 1997 (30.01.97) SE (71) Applicant (for all designated States except US): SCANVIRON- MENT AB [SE/SE]; P.O. Box 241, S-391 23 Kalmar (SE). (72) Inventor; and (75) Inventor/Applicant (for US only): ROSÉN, Björn, Hubert [SE/SE]; St. Rör Pl 7252, S-386 95 Färjestaden (SE). (74) Common Representative: ROSÉN, Björn, Hubert; St. Rör Pl 7252, S-386 95 Färjestaden (SE).		(81) Designated States: AU, CA, NO, US, Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Published <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i> <i>In English translation (filed in Swedish).</i>
(54) Title: PROCESS, USING AMMONIA RICH WATER FOR THE SELECTION AND ENRICHMENT OF NITRIFYING MICRO-ORGANISMS FOR NITRIFICATION OF WASTEWATER		
(57) Abstract <p>The present invention comprises a method for biological oxidation of nitrogen in water, e.g. wastewater, nitrification, by using ammonia-rich water for the selection and enrichment of nitrifying micro-organisms in a separate aerated reaction volume, where organic matter already has been reduced. The nitrifying micro-organisms will get a competing edge compared to other species, as they are being able to obtain energy from the oxidation of ammonia into nitrate. The method can be applied to the activated sludge process by the introduction of a sludge aeration zone on the recycled sludge, and also be combined with a sludge anoxic zone, for denitrification, enabling a more reliable operation of biological nitrogen as well as phosphorus removal, by maximal use of reaction volumes with lower detention time and lower costs. It can also be applied to a fixed bed process. The possibility of stimulating the micro-organisms to higher activity by changing the physical-chemical conditions is also included, as well as improving the sludge separation characteristics. The method is enabling an overall view of the process, integrating different process stages for optimisation and best possible operational results.</p>		

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**PROCESS, USING AMMONIA RICH WATER FOR THE SELECTION
AND ENRICHMENT OF NITRIFYING MICRO-ORGANISMS FOR
NITRIFICATION OF WASTEWATER**

Wastewater is treated in treatment plants by **mechanical** (*primary*), **biological** (*secondary*) and sometimes also (*tertiary*) **chemical treatment**. When using mechanical treatment, suspended solids are separated by some form of sieving, followed by separation, usually sedimentation. The removal of organic matter as well as nutrients (nitrogen and phosphorus) and bacteria, however, is not very high.

For further removal, biological treatment is needed, which means that micro-organisms transform organic matter into bio-mass, or sludge, provided that correct physical-chemical conditions are at hand. To enable this process, access to oxygen, or aerobic conditions, is required, which is obtained by some form of aeration system. Furthermore, nutrients like nitrogen and phosphorus must be present, which is the case in municipal wastewater in abundance. When using biological treatment, more than 90 % organic removal can be achieved, as well as high removal of bacteria. Nutrient removal, however, will be limited to some 30 % nitrogen and phosphorus removal by assimilation into the bio-mass, which is removed as excess sludge for separate treatment and recovery, or disposed of.

For further reduction of finely dispersed impurities, remaining after the previous treatment, and particularly for the removal of phosphorus, chemical treatment can be used. Chemical treatment involves the addition of a coagulant, which is able to coagulate and flocculate remaining impurities into chemical flocs, also precipitating phosphorus, resulting in more than 90 % removal of phosphorus. When this tertiary chemical treatment is introduced as **post-precipitation** after the primary and biological treatment, the removal of organic matter, phosphorus and bacteria can be considerably increased. The coagulant can also be fed into the primary settling stage, **pre-precipitation**, or in the biological stage, **simultaneous precipitation**, which in many Swedish treatment plants has resulted in the possibility of using the existing tertiary stage for other purposes, or as an extra safety.

The obtained removal of nitrogen is thus by assimilation, or some 30 %. If the sludge is stabilised for possible reuse in agriculture, some of the assimilated nitrogen is released, and re-circulated with the reject water after dewatering, which will result in only 15-20 % nitrogen removal.

Below, the conventional methods for wastewater treatment will be presented, in Figure 1-5, with emphasis on biological nitrogen removal.

WATER TREATMENT

In water treatment as well, nitrogen can give problems. The increased use of fertilisers, not rarely overdosed, has resulted in higher contents of nitrates in rivers and lakes, as well as in the groundwater, all being used as a potable water source. Nitrate can be reduced to nitrites, which is toxic to infants.

TREATMENT PROCESSES

In order to achieve further removal of nitrogen, ion exchange might be used, though quite costly. Instead biological treatment methods have been developed to first biologically degrade nitrogen compounds to nitrate, nitrification, and then remove nitrogen by dissimilative reduction to gaseous nitrogen by biological denitrification. For potable water treatment nitrogen is often present as nitrate, and biological denitrification can be used.

BIOLOGICAL TREATMENT

All treatment of (waste) water includes the separation of suspended matter, either in the untreated (waste) water, or in the biological or chemical treatment stage. Biological treatment involves the transformation of organic matter by microorganisms into biological flocs, which are separated from the water. Chemical treatment means the transformation of colloidal or fine suspended solids, as well as dissolved matter like phosphorus, into chemical flocs, which are separated from the water.

Normally, the transformation processes are discussed, being very complex. The separation of flocs, however, is more often giving problems, not least at peak flows.

With the presented invention the transformation process with nitrification and denitrification can be more effective, as well as the separation properties of the flocs, for an overall better performance in smaller volumes, which is of great importance by upgrading of treatment plants.

Definitions

Nitrification	= ammonia (NH_4) \Rightarrow nitrite (NO_2) \Rightarrow nitrate (NO_3)
Denitrification	= nitrite (NO_2) \Rightarrow gaseous nitrogen (N_2)
BOD	= biological oxygen demand (measurement for organic matter)
COD	= chemical oxygen demand (measurement for organic matter)
Aerobic	= oxygen rich environment (also called oxic zones)
Anoxic	= no dissolved oxygen, though chemically bound oxygen present
Anaerobic	= no dissolved chemically bound oxygen
Excess sludge	= produced sludge to be removed also called Surplus sludge or Waste activated sludge
Sludge age	= detention time of the sludge in the process = the sludge amount in the process divided by the excess sludge, measured in days

In biological treatment, oxygen is fed into the wastewater by aeration or some other means, and micro-organisms are then transforming impurities into cells or bio-mass, forming biological flocs. The flocs are then separated as a sludge in the separation stage. The process can be carried out as a fix film process with immobilised micro-organisms, e.g. in trickling filters, rotating biological discs or suspended carriers. The mostly used process, however, is the activated sludge process, is using suspended micro-organisms, which are separated and recirculated from the separation stage, thus building up a large concentration of active micro-organisms in an aerated (oxygenated) reactor, where rapid degrading of organic matter will be achieved.

Below, the well known technology for biological treatment and the invention will be presented and discussed, referring to the following figures:

- **Figure 1A** shows an activated sludge process for the removal of organic matter
- **Figure 1B** shows an activated sludge process with sludge aeration, biosorption
- **Figure 2** shows an activated sludge process with nitrification
- **Figure 3** shows a two-stage activated sludge process with post-denitrification
- **Figure 4** shows an activated sludge process with pre-denitrification
- **Figure 5** shows an activated sludge process with pre-denitrification and sludge anoxic zone

THE ACTIVATED SLUDGE PROCESS

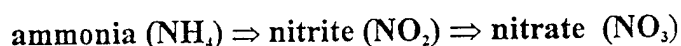
In a conventionally designed activated sludge process, organic matter is transformed into biological flocs by the micro-organisms, and organic nitrogen is degraded into ammonia nitrogen **Figure 1A**.

The activated sludge process will give a high removal of organic matter, measured as BOD, though having a disadvantage by the large amount of recirculated sludge. At peak flow conditions, e.g. by rain storms or in snow melting periods, there is a risk for the sludge not having time to settle and thus following the discharged water, so called solids carry over. Another problem with the process is that at unfavourable composition of the wastewater, or when the process is not properly followed up, the 'wrong' type of micro-organisms might be formed, e.g. filamentous micro-organisms, resulting in poor floc separation conditions, called 'sludge bulking'.

One way of reducing the impact of peak flows is to introduce a separate sludge aeration volume. The recirculated sludge will be activated, resulting in rapid removal of organic matter, when the sludge is mixed with incoming wastewater in the contact volume. At the same time, a sludge storage is obtained, separated from the incoming water. The modification is often called 'bio-sorbition', requiring less total volume, **Figure 1B**.

NITRIFICATION

In order to achieve biological denitrification, it is imperative that the nitrogen is oxidised into nitrate, nitrification, which occurs in two stages, using different micro-organisms:



In order to achieve nitrification, longer detention time and/or higher temperature is required, compared to only removing organic matter (BOD), and in many treatment conventionally designed plants, nitrification will occur at low loads during the summer time, sometimes giving problems when post-precipitation is in use.

During the nitrification process alkalinity is reduced and the pH-value might decrease, making it impossible to optimally operate post-precipitation without adjusting the pH.

The nitrification requires a higher sludge age and higher detention time than for just BOD-removal, **Figure 2**. The oxygen consumption will also increase, normally more than 50 %.

The ammonia nitrogen is transformed via nitrite to nitrate using autotrophic micro-organisms with a longer regeneration time than the micro-organisms, which remove organic matter, BOD. That is the reason for the necessary longer detention time, as otherwise the nitrifying micro-organisms, nitrifiers, will be washed out from the process. The regeneration time for the nitrifiers is some 3 days, and a sludge age of 10 days is normally required. Practical experience, however, shows that at a sludge age of 8 days, stable nitrification/denitrification has resulted in effluent values of some 8 mg total nitrogen per litre at a temperature of 8 degrees.

DENITRIFICATION

The **denitrification**, requires an anoxic environment, i.e. no dissolved oxygen, where the micro-organisms takes the necessary oxygen from the nitrates, being transformed into gaseous nitrogen into the atmosphere, **Figure 3**. The alkalinity and pH-value is increased. The denitrification requires access to easy degradable carbon, and at the first treatment plants for biological nitrogen removal, methanol was dosed into a second activated sludge stage for **post-denitrification**. A two-stage process will increase both investment and operation costs, as expensive organic matter has to be used, where the process previously has removed organic matter.

PRE-DENITRIFICATION

In South Africa, a process modification with **pre-denitrification** was presented in the seventies, where the incoming organic matter in the wastewater was used as a carbon source for recirculated nitrified water from the following nitrification stage,

Figure 4. The load in the nitrification stage will be reduced, as some of the organic matter, BOD, will be used in the pre-denitrification. The operation costs will be lower, as less oxygen is needed and external carbon will be needed.

The pre-denitrification can be introduced as soon as nitrification has been reached and the process has several advantages.

The so called BarDenPho-process after its inventor, James Barnard, was expected to have possibilities in a colder climate like in Sweden, and the technical solutions used there, and was introduced in full scale in the city of Falkenberg 1983.

The possible nitrogen removal is limited by the amount of recycled nitrate to the anoxic zone, or

$$N_{red} = 100 * (Q_R + Q_N)/(Q + Q_R + Q_N) \%$$

For example, the possible nitrogen reduction at 100 % recycle of sludge and nitrate water will be $100 * 100 / (100 + 100) = 50 \%$, 200 % recycle $100 * 200 / (100 + 200) = 67 \%$, and so on, **Figure 4.** Additional to the nitrogen, being removed as gaseous nitrogen, will come the assimilation of nitrogen in the sludge, which, depending on the characteristics of the wastewater and to some extent the process design, normally is some 6-8 % of the sludge production.

In South Africa, nitrogen removal is necessary for the re-use of water, when it is important to keep the salt content low. The target is highest possible removal, which led to 500-800 % total recycle.

If the requirement is less stringent, 10-15 mg/l, i.e. like in Sweden, it is sufficient with only sludge recycle, possibly with a little higher capacity. In many full-scale tests, the denitrification in the anoxic zone has been limited, which was interpreted as lack of easily degradable carbon. Instead the poor results were dependant on too high recycle, in accordance to the original concept, giving too short detention time and wrong conditions for denitrification.

By only closing down nitrate recycle pumps, dramatic improvement has been achieved, resulting in decreased discharge from 20 to 10 mg nitrogen per litre. As a summary, the following conditions must prevail for efficient nitrogen removal:

Nitrification, which requires

- Sufficient sludge age (normally more than 8 days)
- Sufficient alkalinity
- Correct pH-value (preferably 8,0-8,5)
- Oxygen content (> 2 mg/l)
- Not too low temperatures
- Efficient (not inhibited sludge)

Denitrification, which requires

- Access to easily degradable carbon
- No dissolved oxygen
- Low redox potential
- Efficient (not inhibited sludge)

MAX USE OF REACTION VOLUMES

Sludge anoxic zones

It is imperative to have sufficient number of micro-organisms in the system for the required task, and particularly not to lose sludge at peak flows or other disturbances. In order to achieve this, it is a question to design the reaction volume and separation stages correctly, as well as to have an operation strategy for optimal use of the treatment plant. It is evident, that a plant should be operated with highest possible sludge content, and at the same time ascertain that the sludge will not be lost. This can be achieved by a correct design of the separation stage and an overall operation strategy with safety and seeding possibilities.

By the introduction of a sludge anoxic zone for the recycled sludge, maximal sludge amount per unit volume will be obtained, and consequently also highest possi-

ble denitrification, provided a carbon source is available. The carbon source can be a supernatant from a primary thickener, or as an external source, preferably ethanol. Another possibility can be to use part of the influent raw sewage after pre-treatment, where the influent raw BOD will be the carbon source. Thus the primary (pre-precipitation) stage and the biological treatment will be less loaded, resulting in lower operation costs and higher capacity.

Another advantage with the sludge anoxic zone is the 'anoxic biosorption' with a sludge storage, reducing the impact of short peak loads on the process.

In order to get better control and monitoring, the process can be operated with on-line instrumentation, preferably ammonia metering in the sludge aeration zone, and pH/redox-metering in the sludge anoxic zone.

BIOLOGICAL PHOSPHORUS REMOVAL

In order to enable biological phosphorus reduction, no nitrate can be present. As the recycled sludge will have the same nitrate content as the effluent from the process, and consequently cannot be led to an anaerobic zone without removal of nitrate. The best way of achieving this is to introduce a sludge anoxic zone on the recycled sludge. Thus the reaction volumes will be optimally used

Anaerobic zones

A process design with a sludge anoxic zone will automatically enable biological phosphorus removal, as anaerobic conditions will come forth as soon as nitrate is used up in the recycled sludge. Biological phosphorus removal means that more phosphorus is assimilated in the excess sludge in the anaerobic zone (no dissolved oxygen or nitrate). The anaerobic zone will give a competing edge to a certain type of micro-organisms, acinobacter, which in an aerobic environment can obtain energy by taking up phosphorus, and in an anaerobic environment by taking up organic matter and releasing phosphorus. A correctly bleeding out of excess sludge will contain 5-6 % phosphorus, compared to normally some 1 %.

Control of sludge bulking

Some release of phosphorus will happen, however, during sludge stabilisation, and end up in the reject water after dewatering. An anaerobic stage will give another great advantage, as the risk for sludge bulking will be considerably reduced, as the filamentous bacteria are disfavoured in such a stage, and thus the separation characteristics of the flocs will be ascertained.

Filamentous micro-organisms can otherwise result in a voluminous sludge, difficult to effectively separate from the water.

METHOD ACCORDING TO THE INVENTION

The present invention is illustrated by **Figure 6**, and comprises a method for improved biological oxidation of nitrogen in water, e.g. wastewater, **nitrification**, by creating a reaction volume for the **selection and enrichment** of nitrifying micro-organisms, followed by biological **denitrification**. The method will make maximum use of reaction volumes, enabling shorter detention time and lower operational costs, and at the same time achieve a more reliable operation for nitrogen removal.

The process is also comprising a wholistic view of the overall process design, with integration and optimisation of different process stages for best possible results. The possibility of stimulating the micro-organisms to higher biological activity is also included, by controlling the physical-chemical conditions, and/or the possible addition of a carbon source for improved denitrification. For better sludge properties, lime can be dosed and/or an anaerobic zone can be introduced, also enabling biological phosphorus removal, for less dosage of coagulant and consequently less chemical sludge to handle.

USING AMMONIA RICH WATER FOR THE SELECTION AND ENRICHMENT OF NITRIFYING MICRO-ORGANISMS

In a specially arranged aerobic reaction volume, **4**, where most of the organic matter has been previously removed, **3**, ammonia rich water with little organic matter, **14**, is fed, e.g. reject water from dewatering of digested sludge, **12**, for the intended nitrification.

The nitrifying micro-organisms will get a competing edge compared to other species, as they are the only ones being able to obtain energy from the oxidation of ammonia into nitrate, thus resulting in the selection and enrichment of nitrifying micro-organisms in the sludge, being used in the first stages of the biological treatment process, **2, 3, Figure 6**.

In **Figure 6** the method is shown

1. Influent of water after possible pre-treatment
2. Reaction volume for possible denitrification in anoxic zone(s)
3. Reaction volume for removal of organic matter
4. Reaction volume for nitrification in accordance with the invention
5. Separation of biological sludge
6. Discharge of biologically treated water
7. Recycle of nitrified water for possible denitrification
8. Collection of surplus or waste activated sludge from the process
9. Thickening of surplus sludge
10. Reactor for stabilising sludge, e.g. anaerobic digester
11. Thickener/storage for stabilised sludge
12. Dewatering of stabilised sludge
13. Dewatered sludge for disposal
14. Ammonia rich water, e.g. reject water from dewatering, and supernatant from thickening
15. Possible balancing of ammonia rich water
16. Possible addition of lime for increase of pH-value and alkalinity.
17. Possible addition of carbon source fore more efficient and rapid denitrification

If the method is applied in an activated sludge system, **Figure 7**, it is advantageous to aerate/oxidise the recycled sludge in the reaction volume, **18**, as the sludge content and total sludge amount per unit volume is higher than in the activated sludge aeration tanks. The higher amount of active sludge will contain a large content of nitrifying micro-organisms, and result in a higher sludge age and higher nitrification rate as a larger amount of active bio-mass is available for nitrification.

In **Figure 7** the method is shown, applied to the activated sludge process, where 1-17 is the same as in **Figure 6**, and

18. sludge aeration reaction tank
19. Possible sludge anoxic zone
20. Possible anaerobic zone
21. Possible separate nitrate recycle

22. Possible bypass at peak load conditions or toxic discharge into the wastewater
23. Possible carbon source, e.g. untreated wastewater
24. Possible carbon source from thickener, operated for soluble carbon formation
25. Recirculation of (active) sludge from the separation stage

The method can especially be used when reject water from dewatering of stabilised sludge, *14*, is collected, where by anaerobic digestion 15-20 % of the total nitrogen load otherwise is re-circulated into the inlet, resulting in many advantages, listed below.

The earlier described sludge anoxic zone, *19*, can also be combined with sludge aeration, *18*, in this new modification. Thus even more sludge with active nitrifying micro-organisms is being used, which will increase the sludge age and the denitrification rate

- The 'normal' aeration stage, *3*, will be unloaded and less oxygen/aeration is required. Furthermore, a large amount of sludge is in operation in the sludge aeration volume, *18*, with large capacity for the nitrification of both the added ammonia rich water, *14*, and ammonia in the re-circulated sludge, *25*, if full nitrification is not achieved in the 'normal' aeration, *4*.
- Another advantage is that the operation of the process is less sensitive for peak loads, otherwise resulting in sludge carry-over in the effluent, *6*, from the separation stage. In the worst case complete loss of sludge and consequently nitrification might otherwise occur. The sludge aeration will then be used a storage for seeding at returning to normal operation conditions, enabled by the bypass (*22*, dotted in **Figure 7**) of all or part of the re-circulating sludge, initiated and controlled by flow or by the solids concentration. This operational mode makes it possible to start up the nitrification process rapidly, even during winter conditions, when otherwise several months' start-up might be necessary.
- The by-pass, *22*, might also be used if e.g. toxic or inhibiting matter might occur, possibly controlled on-line by toxic metering or a combination of other measuring parameters at the plant inlet. The by-pass can easily be automated.

- If the ammonia rich water is collected in a balancing tank, *15*, 'dosing' it into the sludge aeration can be done in such a way, that maximal nitrate content is reached at the mixing of aerated sludge with the inlet wastewater in the anoxic zone, *20*, at maximum organic load. The 'dosing' can be controlled by an ammonia metering at the outlet of the sludge aeration.
- Furthermore, the biological flocs can be made heavier by the addition of lime, *16*, which also will increase alkalinity and pH-value if the alkalinity is too low. The effect has been recorded as a 25-30 % increase of the nitrification rate. The lime-dosage can either be applied in the sludge aeration, *18*, or if pre-precipitation is used, before the primary clarification, 25-100 mg/l. When using ferro-salts in the pre-precipitation process, the suspended solids, organic matter and phosphorus removal will be improved in that stage.
- Not only the nitrifying micro-organisms might benefit from the sludge aeration, *18*, as other aerobic micro-organisms will be activated, for rapid removal in the following process stages, in the sludge anoxic zone, *19*, as well as in the anoxic zone, *2*, and the aeration *3*.

When using an external carbon source, *17*, dosing control by pH/redox metering in the sludge anoxic zone, *19*, might be used. If some part of the not pre-precipitated wastewater, *23*, would be used if sufficient carbon is not available, control from a suspended solids metering at the inlet can be used, as the correlation between suspended solids and organic matter, measured as BOD or COD is good enough. Another, more accurate, though more expensive, possibility is using on-line measuring of TOC (total organic carbon) for controlling the feeding of organic matter.

If possible, the carbon source used, *17*, should be internal, e.g. supernatant from the thickeners, *24*, possibly improved by simultaneous acid fermentation and thickening. As a 'backup', the possibility of using an external source, preferably ethanol, as no adaption is necessary for on/off operation.

The overall control would use a computer, under an operational strategy

FIXED FILM PROCESSES

The method can also be used for fixed film processed, **Figure 6**, where in a first stage organic matter is reduced, **3**, before the reactor for nitrification in a fixed bed, **4**, where the ammonia rich wastewater with little organic matter is fed, **14**, e.g. reject water from dewatering after anaerobic digestion.

PATENT CLAIMS

1. Method for biological oxidation of nitrogen in water, e.g. wastewater, **nitrification**, and possible biological removal of the nitrogen, **denitrification**, where water after pre-treatment by sieving, settling etc. is biologically treated in an aerobic system, when solids, colloidal and dissolved matter in the water are transformed by micro-organisms into suspended matter, which can be separated from the water as a biological sludge, which after stabilisation is dewatered, and the reject water, containing high content of ammonia and low content of organic matter, *characterised by* that the ammonia rich reject water, or other ammonia rich water, is fed into the treatment process into an aerobic *reaction volume*, where organic matter already is reduced, for the *selection and enrichment* of nitrifying micro-organisms, before further treatment.
2. Method for biological oxidation in accordance with claim 1, *characterised by* that recirculated sludge in the activated sludge process is aerated or otherwise oxygenated in the reaction volume for the oxidation of ammonia nitrogen and for the activation of micro-organisms in the sludge.
3. Method in accordance with any claim above, *characterised by* that the reject water is balanced for optimal treatment in the process
4. Method in accordance with any claim above, *characterised by* the feeding of ammonia rich water is controlled by an ammonia meter at the outlet of the reactor.
5. Method in accordance with any claim above, *characterised by* that at peak flow conditions the sludge aeration volume is bypassed, and the stored sludge later on can be used for seeding
6. Method in accordance with any claim above, *characterised by* that when necessary, e.g. at peak flows or at industrial discharge, bypass of the reaction volume will be carried out automatically, by impulse from the inlet flow meter and/or suspended solids meter in the aeration or recirculated sludge, or by industrial discharge, by a toxic meter system, working on-line.

7. Method in accordance with any claim above,
characterised by that the sludge aeration volume is followed by a sludge anoxic zone for biological reduction of nitrate into nitrogen gas
8. Method in accordance with any claim above,
characterised by that lime or a calcium carbonate product is dosed, < 100 mg/l, calculated on the inlet flow.
9. Method in accordance with any claim above,
characterised by that lime or a calcium carbonate product is dosed in the pre-precipitation, thus improving the removal and consequently decreasing the load on the biological stage.
10. Method in accordance with any claim above,
characterised by that the dosage is controlled by alkalinity and/or pH-metering.
11. Method in accordance with any claim above,
characterised by that the lime is dosed in the reaction volume.
12. Method in accordance with any claim above,
characterised by that a carbon source is fed into the sludge anoxic zone, from an internal stream, e.g. supernatant from primary thickening
13. Method in accordance with any claim above,
characterised by that the sludge thickening is operated for acid fermentation of the sludge, and thus more easy biologically accessible carbon will be transferred into the supernatant
14. Method in accordance with any claim above,
characterised by that the carbon source is fed as (part of the) pre-treated wastewater into the sludge anoxic zone.
15. Method in accordance with any claim above,
characterised by that the carbon source is fed as part of the pre-treated wastewater, controlled by e.g. suspended solids, TOC or respiration metering in the inlet water.
16. Method in accordance with any claim above,
characterised by that carbon source is fed into the sludge anoxic zone as an external source, preferably ethanol.

17. Method in accordance with any claim above,
characterised by that the feeding of carbon source is controlled by a pH/redoxmeter at the outlet of the sludge anoxic zone
18. Method in accordance with any claim above,
characterised by that an anaerobic stage for control of sludge quality and also for possible biological phosphorus removal is included after the sludge anoxic stage
19. Method in accordance with any claim above,
characterised by that no separate nitrate recirculation is necessary
20. Method in accordance with any claim 1, 3, 4, 6, 8,9,10 and 11 above, *characterised by* that the reaction volume is a fixed bed reactor

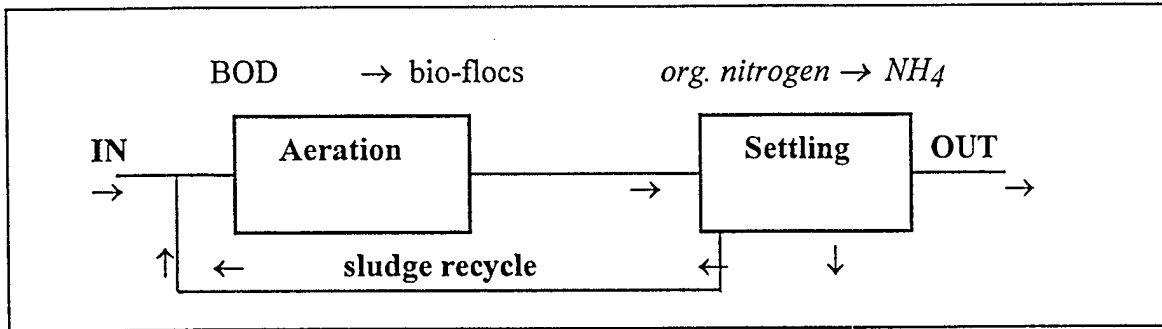


Figure 1 A.

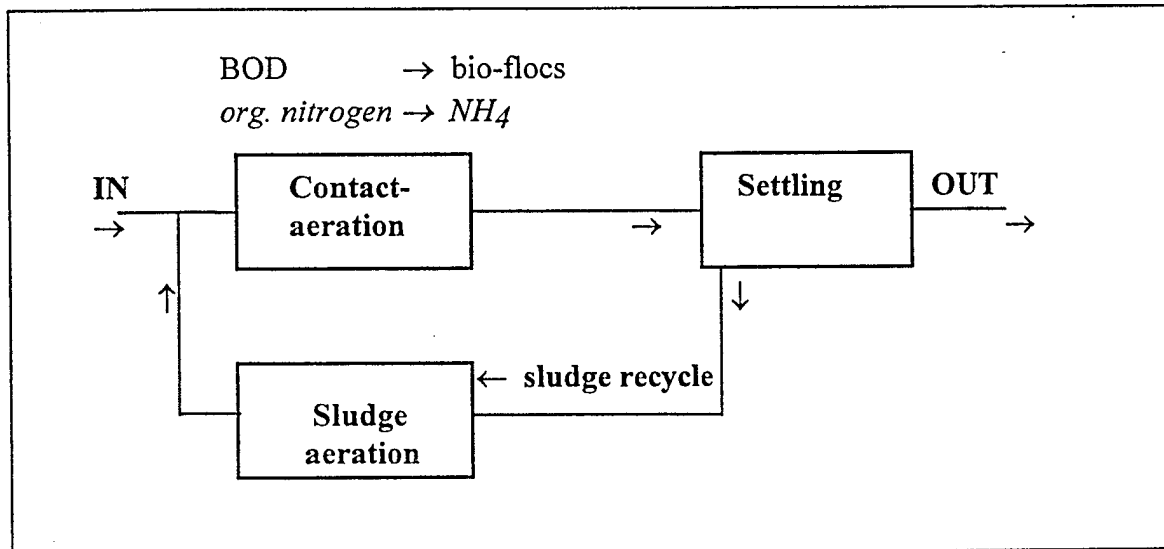


Figure 1 B.

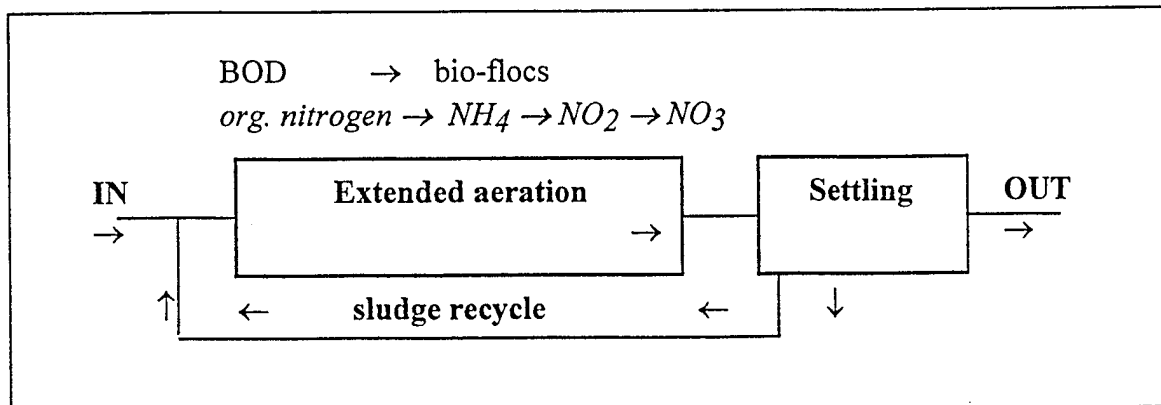


Figure 2.

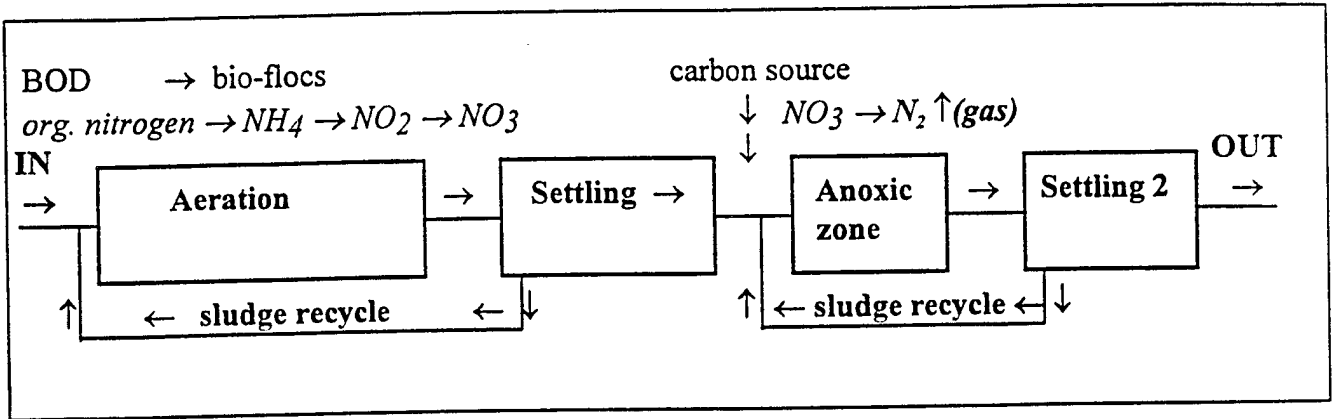


Figure 3.

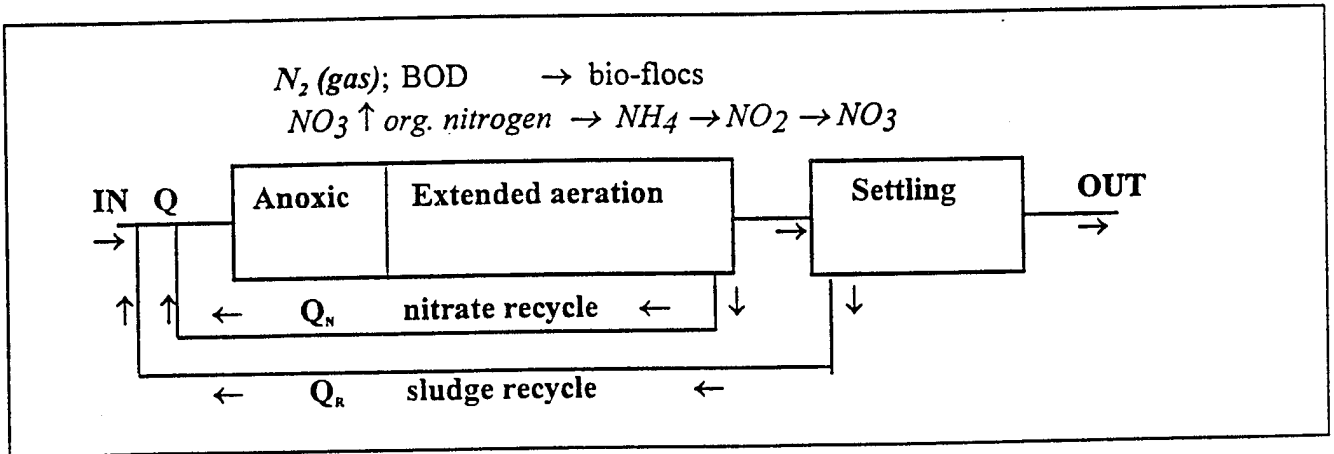


Figure 4.

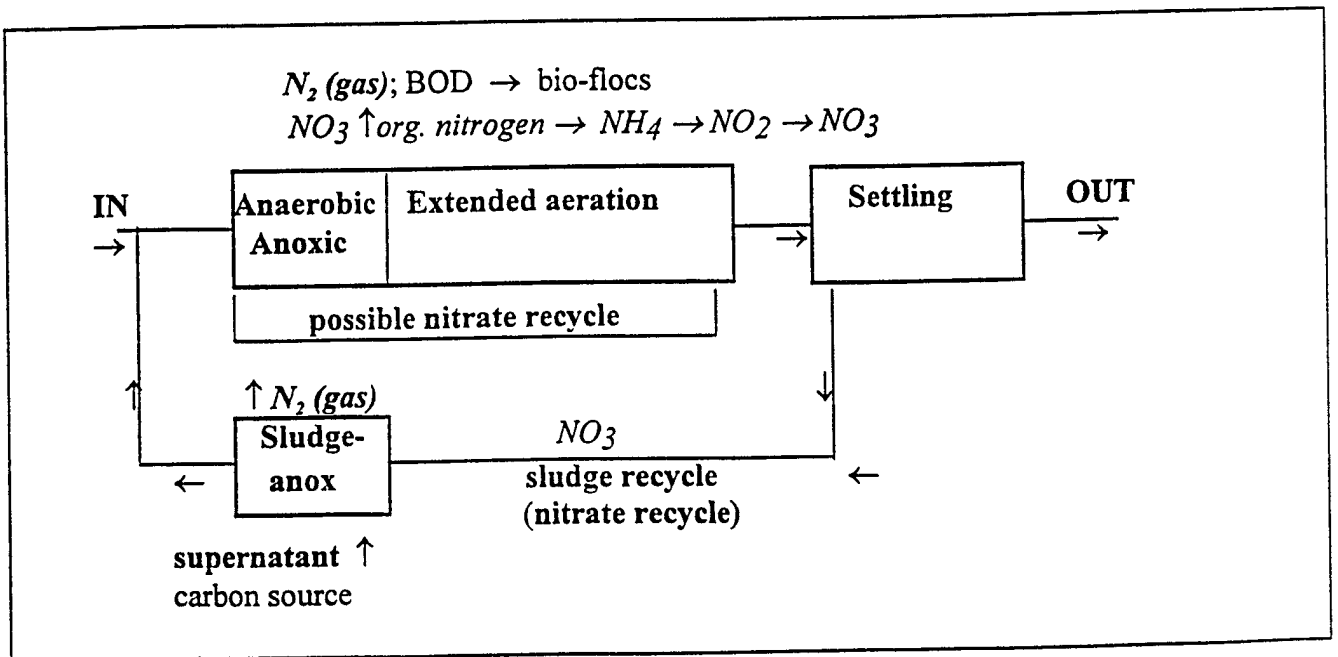


Figure 5.

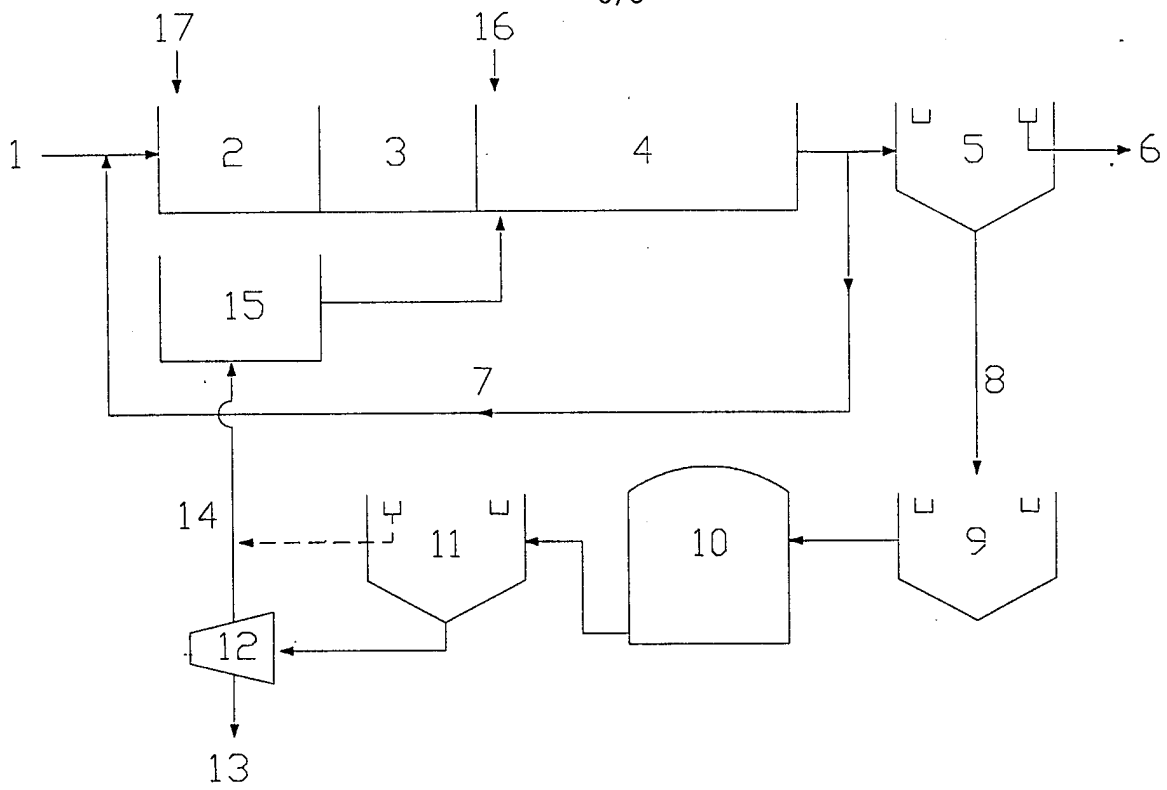


Figure 6.

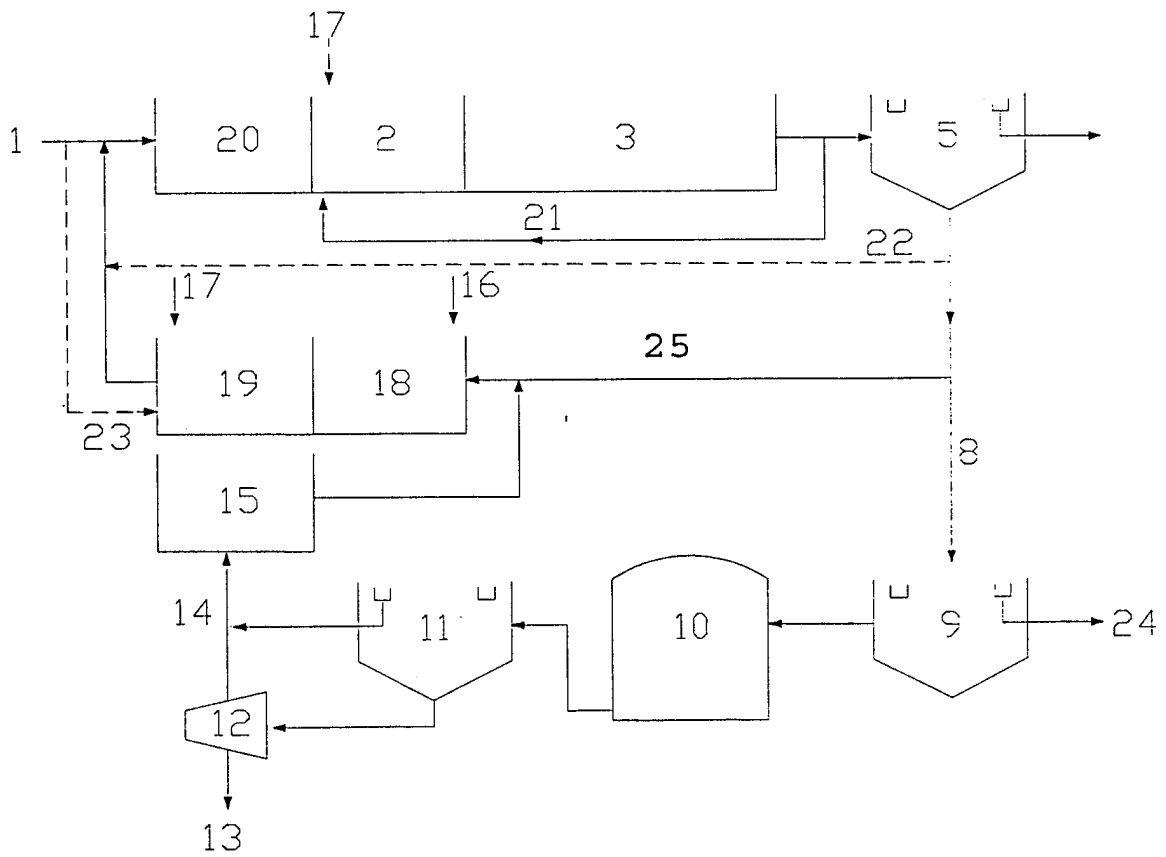


Figure 7.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 98/00120

A. CLASSIFICATION OF SUBJECT MATTER		
IPC6: C02F 3/00, C02F 3/12, C02F 3/30 According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols)		
IPC6: C02F		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
SE,DK,FI,NO classes as above		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	SE 91031302 A (PETER HASSELROT), 26 April 1993 (26.04.93), page 2, line 23 - line 25; page 3, line 4 - line 7; page 3, line 24 - page 4, line 14, figure 1 --	1-3,8
A	DE 2924449 A1 (UNION CARBIDE CORP), 8 January 1981 (08.01.81), page 4, line 8 - line 11; page 42 - page 45, figures 4,6 --	1-2,7,11
A	EP 0534351 A2 (THYSSEN INDUSTRIE AG), 31 March 1993 (31.03.93), page 2, line 10 - line 27; page 3, line 5 - line 15, claim 1 --	1
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search		Date of mailing of the international search report
1 July 1998		03-07-1998
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86		Authorized officer Bo Bergström Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 98/00120

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 3394814 A (O.E. ALBERTSON), 30 July 1968 (30.07.68), column 5, line 4 - line 43, figure 1 --	1
A	WO 9306049 A1 (THE DOW CHEMICAL COMPANY), 1 April 1993 (01.04.93), page 3, line 25 - line 30, figure 1 --	1
A	US 5356537 A (JESSE M. THURMOND ET AL), 18 October 1994 (18.10.94), figure 1, claim 1 --	1
A	EP 0346013 A1 (ORANGE WATER AND SEWER AUTHORITY), 13 December 1989 (13.12.89), page 6, line 39 - line 53, figure 5 -- -----	14

INTERNATIONAL SEARCH REPORT

Information on patent family members

09/06/98

International application No.

PCT/SE 98/00120

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
SE 91031302 A	26/04/93	NONE	
DE 2924449 A1	08/01/81	NONE	
EP 0534351 A2	31/03/93	GB 2259699 A,B	24/03/93
US 3394814 A	30/07/68	BE 692350 A CH 475919 A DE 1584895 A ES 335311 A FR 1513497 A GB 1124612 A NL 6700163 A SE 335305 B	16/06/67 31/07/69 04/12/69 01/04/68 00/00/00 00/00/00 10/07/67 17/05/71
WO 9306049 A1	01/04/93	AU 2593692 A CA 2119891 A EP 0605520 A JP 7501974 T US 5308491 A	27/04/93 01/04/93 13/07/94 02/03/95 03/05/94
US 5356537 A	18/10/94	AU 6667094 A WO 9424055 A	08/11/94 27/10/94
EP 0346013 A1	13/12/89	SE 0346013 T3 AU 620402 B AU 3581089 A CA 1331897 A DE 6890459 U JP 2086895 A US 4874519 A US 4999111 A US 5022993 A	20/02/92 07/12/89 06/09/94 11/03/93 27/03/90 17/10/89 12/03/91 11/06/91