Abnormal Condition: Nitrite Accumulation

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1 Process and Problem Summary

1.1 Basic Aim

Nitrogen and Carbon Removal in a single SBR process

1.2 Problem/Abnormal Condition

Nitrite (NO_2^-) accumulation

Critical when the nitrite concentration in the effluent exceeds the allowed limit of 0.6 [mg/l].

1.3 Hipothesis

- *Incomplete nitrification*:
  Nitrite oxidation does not take place
- *Incomplete denitrification*:
  Reduction of Nitrite does not take place

2 Possible Cause Effect Relationships

ORP

- Nitrite oxidisers prefer high ORP

DO

- Low dissolved oxygen concentrations are unfavorable for nitrite oxidisers

pH

- Low pH may cause inhibition of the nitrification
- High pH increases the concentration of NH_3(see next paragraph)

Ammonia

- Unionised ammonia (NH_3) and ionised ammonia (NH_4^+) form an equilibrium that depends upon the pH and the water temperature. At a pH of 7.0 most of the ammonia is in the ionised form while at a pH of 8.0 the majority is in the unionised form (i.e. as the pH falls, the ammonia equilibrium shifts in the direction of ionised ammonia). [Possible reference: K. Emerson, R.C. Russo, R.E. Lund, and R.V. Thurston (1975): "Aqueous ammonia equilibrium calculations; effect of pH and temperature", Journal of the Fisheries Research Board of Canada Vol. 32, pp. 2379-2383.]
- can inhibit nitrite oxidisers

Temperature

- is an ecological factor
- has an influence on the ammonia equilibrium

Nitrogen Load

- sudden changes can cause temporary unsteady conditions
- may cause an accumulation of nitrites

Sludge Retention Time (SRT)

- Excess wastage and short sludge ages can cause wash out of nitrifiers (slow growing organisms)

Carbon Load

- Low carbon load can lead to an incomplete denitrification process

Operational Sequence

- Long-term idle periods have an impact on the nitrogen removal performance [Morgenroth et.al. 2000].

Figure 1 presents a directed graph representation of cause-effect relationships.

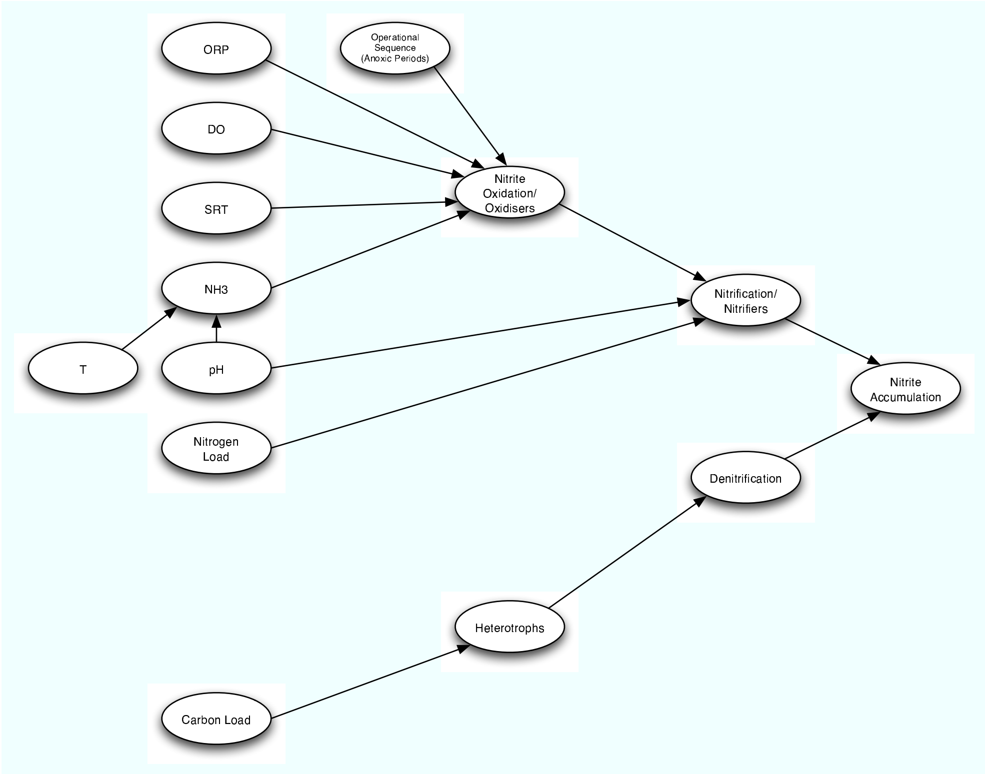

Figure 1: Cause Effect Relationships (DG)

A Glossary

heterotrophic organisms that need complex organic compounds of nitrogen and carbon for metabolic synthesis

autotrophic organisms that need simple inorganic compounds (CO_2or carbonates) and simple inorganic nitrogen compounds for metabolic synthesis

facultative taking place under some conditions but not under others; in the context of this document, it refers to organisms that can use both dissolved free oxygen and combined oxygen (like nitrates and sulphates) as electron receptors

strict inflexibly maintained or adhered to; organisms that are bound to use dissolved free oxygen (strict aerobes) and organisms that are bound to use nitrates and sulphates (strict anoxic) as electron receptor

Nitrification refers to the oxidation of ammonia to nitrite and then nitrate ($NH_4^+ \rightarrow NO_2 \rightarrow NO_3^-$). This process occurs primarily by a group of aerobic chemoautotrophs called the nitrifiers. While heterotrophic nitrification may occur, rates are low and quantities of nitrate produced are relatively small compared to the chemoautotrophs. All nitrifiers are aerobic, and nitrification proceeds at C:N ratios of less than 20, when N is abundant. Nitrification is a two step process:

1. *Ammonium Oxidation*:
   The microorganisms involved are called the ammonia oxidizers, they are chemoautotrophs growing with ammonia as energy substrate and CO_2 as main carbon source.

   $$NH_4^+ + \frac{1}{2}O_2 \rightarrow NH_2OH + H^+ \text{ (Ammonia Monooxygenase)}$$

$$NH_2OH \rightarrow NO_2^- + HOH + H^+ \text{ aerobic conditions}$$

Overall reaction:

$$NH_4^+ + \frac{3}{2}O_2 \rightarrow NO_2^- + HOH + 2H^+$$

Under anerobic conditions the following reaction may occur:

$$NH_2OH \rightarrow NOH \rightarrow N_2O$$

2. *Nitrite Oxidation*:
   The microorganisms involved are called nitrite oxidisers.

$$NO_2^- + \frac{1}{2}O_2 \rightarrow NO_3^-$$

Ecological factors are: pH, T

[Brock (1999), Karp et.al. 2002a, Karp et.al. 2002b]

Denitrification refers to the reduction of nitrate to nitrogen gas or to organic nitrogen compounds.

$$NO_3^- \rightarrow NO_2^- \rightarrow N_2$$

There are two types of denitrification:

1. *Assimilative*:
   This pathway uses nitrate as a nitrogen source by reducing it and incorporating the nitrogen atoms into organic molecules.

2. *Dissimilative*:
   This pathway returns nitrogen atoms to the atmosphere by reducing nitrate to nitrogen gas via intermediate steps. It is the pathway we are more interested in for wastewater treatment and is usually done by facultative anaerobe microorganisms.

   (a) Reduction of Nitrate to Nitrite:
   $2HNO_3 \rightarrow 2HNO_2 + 4e^-$ and $2NADH - H \rightarrow 2NAD$ (Dissimilatory Nitrate Reductase)

   (b) Reduction of Nitrite to Nitric oxide:
   $2HNO_2 \rightarrow 2NO + 2e^-$ and $NADH - H \rightarrow NAD$ (Dissimilatory Nitrite Reductase)

   (c) Reduction of Nitric Oxide to Nitrous Oxide:
   $2NO \rightarrow N_2O + 2e^-$ and $NADH - H \rightarrow NAD$ (Dissimilatory Nitric Oxide Reductase)

   (d) Reduction of Nitrous Oxide to Dinitrogen:
   $N_2O \rightarrow N_2 + 2e^-$ and $NADH - H \rightarrow NAD$ (Dissimilatory Nitrous Oxide Reductase)

   Ecological factors: pH, Temperature, oxidizable carbon source (electron donor), absence of oxygen, presence of nitrate or nitrite

[Brock (1999), Karp et.al. 2002c, Watmough et.al.]

SBR Process Sequencing Batch Reactor Process; phases of the process are temporally separated (instead of spatially as in continous systems).

NAD/NADH Nicotinamide Adenine Dinucleotide is a carrier of electrons produced in biological oxidations. The molecule exists in two forms that vary in whether or not they are carrying electrons. $NADH$ is the reduced form of the molecule (carries electrons) and NAD^+ is the oxidized form of the molecule (lacks electrons).

Catabolism is a process in which a cell breaks down complex molecules to produce energy and reducing power, it is therefore normally exothermic. It is half of the coupled process of metabolism, the other part being anabolism.

Anabolism is a contructive metabolic process whereby energy is consumed to synthesize or combine simpler substances, such as amino acids, into more complex organic compounds, such as enzymes and nucleic acids.

References

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