Biological Nutrient Removal from Domestic Wastewater for maintaining River Water Quality: A Review

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Abstract:- Nutrient removal is a key factor in maintaining the natural water cycle following human interferences and continued population growth has made domestic wastewater treatment both a requirement and a challenge in all around the world. Nutrient presents like nitrogen and phosphorus in treated wastewater due to inefficiency of wastewater treatment causes eutrophication(algal blooms) in water bodies and deteriorate river water quality ,because treated wastewater is discharged to surface water bodies. Nitrogen & Phosphorus not efficiently removed in conventional biological treatment. BNR(Biological Nutrient Removal) process working with BOD, COD and Nutrient removal from wastewater.

Keywords:- BNR; Nitrogen; Phosphorus; Domestic Wastewater; River water quality

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Introduction

Nitrogen and phosphorus are essential growth elements for microorganisms used in wastewater treatment; therefore, during all biological treatment, some level of nutrient removal occurs. The resulting cell mass contains about 12 percent nitrogen and 2 percent phosphorus by weight (Jeyanayagam, 2005). When a treatment system is engineered to remove nutrients greater than these metabolic amounts, it is called biological nutrient removal (BNR). In essence, BNR is comprised of two processes: biological nitrogen removal and enhanced biological phosphorus removal (EBPR) (Marta et al.).

Biological Nitrogen Removal

Key biological nitrogen removal reactions are nitrification and denitrification (Figure 1). Other related reactions include ammonification (conversion of organic nitrogen to ammonia nitrogen) and nitrogen uptake for cell growth(WEF, 2007).

Nitrification: Nitrification is the oxidation of ammonia to nitrite and nitrate. The key organism involved are thought to be *Nitrosomonas* and *Nitrobacter*. These are autotrophs that oxidize inorganic nitrogen compounds for energy:

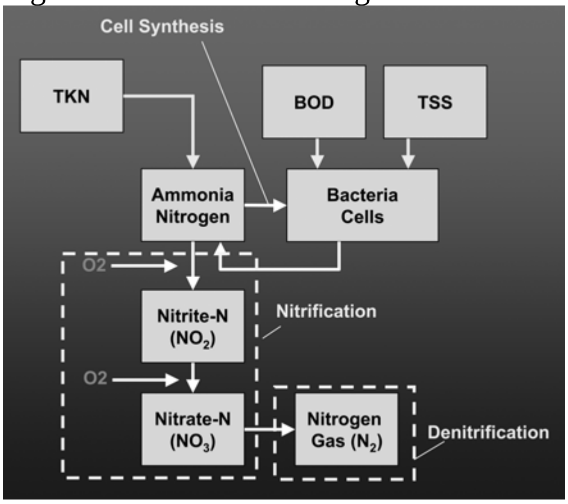

Fig 1. Nitrogen removal from wastewater

Nitrosomonas:

$$2NH_4^+ + 3O_2 \rightarrow 2NO_2^- + 2H_2O + 4H^+ + \text{New cells}$$

Nitrobacter:

$$2NO_2^- + O_2 \rightarrow 2NO_3^- + \text{New cells}$$

(WEF, 2007) Carbon for cell growth is obtained from carbon dioxide. Consequently, organic substrate (BOD) is not a prerequisite for the growth of nitrifiers (Urdalen, NTNU). It is now known that organisms other than Nitrosomonas and Nitrobacter can also mediate the nitrification process; therefore, the term ammonia oxidizing bacteria (AOB) is used to refer to them collectively. In BNR systems, nitrification is the controlling process for two reasons: (1) AOBs lack functional diversity. They represent about 2 percent of the microbial mass. (2) AOBs have stringent growth requirements and are sensitive to environmental conditions. Nitrification results in the conversion of nitrogen from a reduced form (ammonia) to an oxidized form (nitrate). It is not in itself a significant nitrogen removal mechanism.

__Denitrification__: Denitrification must follow nitrification to achieve significant total nitrogen removal. Denitrification is the reduction of nitrate to nitrogen gas by certain heterotrophic bacteria. The process requirements are anoxic conditions and a source of rapidly biodegradable organic matter (RBOM). Anoxic refers to the presence of combined oxygen (nitrate and nitrite) and the absence of free or dissolved oxygen (DO). The simplified reaction is:

$$NO_{3^-} + \text{RBOM} \longrightarrow (N_2\,(\text{gas}) + CO_2 + H_2O + OH^- + \text{New cells})$$

Denitrification results in the recovery of 3.6 mg of alkalinity as CaCO3 and 2.9 mg of oxygen per mg of NO3-N reduced; therefore, by combining nitrification (aerobic) and denitrification (anoxic), partial alkalinity recovery and oxygen credit can be attained. An additional benefit of incorporating an anoxic selector is improved sludge settleability (WEF, 2007). The denitrification rate (g NO3-N reduced/g MLVSS.d), which determines the amount of nitrate denitrified, is primarily a function of: (1) Availability of RBOM and (2) temperature (Jeyanayagam, 2005).

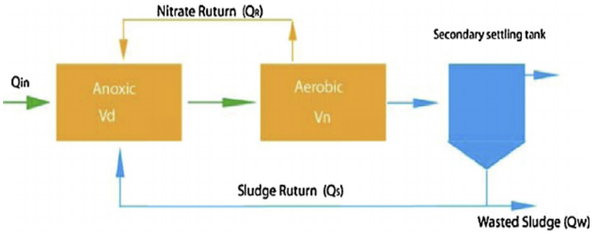

Fig 2. Diagram of BNR

Biological Phosphorus Removal

As noted previously, the typical phosphorus content of MLSS in conventional secondary treatment is approximately 2 percent by weight (Urdalen, NTNU). Enhanced biological phosphorus removal (EBPR) refers to phosphorus uptake greater than these metabolic requirements by specialized aerobic heterotrophs called Phosphorus Accumulating Organisms (PAOs) (Marta et al.). Acinetobacter is the most widely recognized PAO. The phosphorus content of the biomass can be as high as 10 percent by weight, but is typically in the range of 3 to 5 percent; hence, the biological phosphorus removal capability of a system is directly related to the fraction of PAOs in the MLSS. Key process features that favour the selection of PAOs include:

- Anaerobic zone with adequate RBOM-in particular, volatile fatty acids (VFAs).
- Subsequent aerobic zone.
- Recycling of the phosphorus-rich return sludge to the anaerobic zone

In the anaerobic zone (Figure 3) (WEF, 2007), the PAOs take up and store VFAs as carbon compounds such as poly-b-hydroxybutyrate
(PHB). Note that PAOs, being aerobes, can not use the VFAs for cell growth in the anaerobic zone. Instead, the VFAs are used to replenish the cell’s stored PHB for subsequent utilization in the aerobic zone. In other words, in the anaerobic zone the PAOs do not multiply, but get fat! The energy required for PHB accumulation is provided by the cleavage of another storage product,

the inorganic polyphosphate granules. This splitting of energy-rich polyphosphate bonds results in the release of phosphorus and may be likened to a battery discharging.

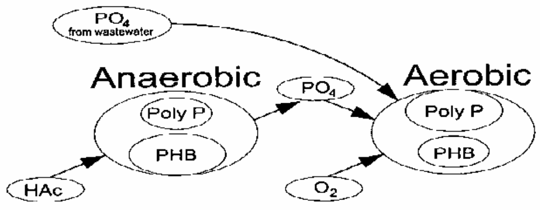

Fig 3. Chemistry of Phosphorus removal

In the subsequent aerobic zone, the PAOs use the internally stored PHB (Marta et al.) as a carbon and energy source and take up all the phosphate released in the anaerobic zone and additional phosphate present in the influent wastewater to renew the stored polyphosphate pool (recharging of the battery). This is because 24 to 36 times more energy is released by PHB oxidation in the aerobic zone than is used to store PHB in anaerobic zone; hence, the phosphorus uptake is significantly more than the phosphorus release.Net phosphorus removal is realized when sludge is wasted. When the phosphorus rich return sludge is recycled to the anaerobic zone, the process is repeated (Figure 4).

In short, the complex biochemical reactions of the EBPR process are fuelled by the cyclical formation and degradation of stored organic compounds (e.g. PHB), in concert with the degradation and formation of inorganic polyphosphate granules (WEF, 2007). Some PAOs have the capability to denitrify. Denitrifying PAOs (DePAO) use nitrate instead of free oxygen to oxidize their internally stored PHB and effect phosphorus uptake in the anoxic zone. The PAOs require higher energy than other heterotrophs (non-PAOs) to accomplish the cyclical reactions associated with the EBPR process. The two most critical factors that favour the proliferation of PAOs, and therefore the reliability of EBPR are: (1) the integrity of the anaerobic zone and (2) the availability of VFAs.

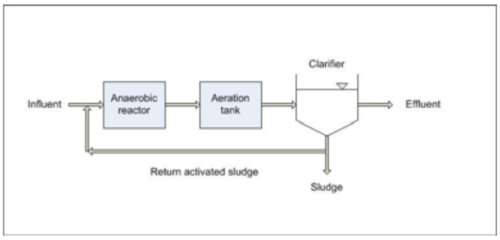

Fig 4. Biological Phosphorus Removal

Sensitivity of BNR

The BNR process is very sensitive to influent characteristics. In particular, VFAs play a central role in enhancing phosphorus removal and denitrification rates. The BOD:TP and BOD:TKN ratios of the bioreactor influent are commonly used as indicators of wastewater's amenability to BNR. The minimum acceptable ratios are (Jeyanayagam, 2005):

BOD:TP	20:1 to 25:1
BOD:TKN	2:1 to 3:1

If the influent BOD:TP is low (BOD limited), adequate VFAs may not be available and phosphorus removal could be compromised. Likewise, low BOD:TKN ratio could result in poor denitrification. Dilute influent, excessive BOD removal in the primary clarifiers, or significant recycled phosphorus and nitrogen loads from sludge processing operations may cause BOD limited conditions. A note of caution: The nitrogen and phosphorus loads in recycle streams from sludge handling and processing operations should be included in determining these ratios.

Nutrient Sources and Pathways

Some of the nutrients come from natural processes, such as decomposition of plant and animal material. During the later stages of eutrophication the water body is choked by abundant plant life due to higher levels of nutrients such as nitrogen and phosphorus. Human activities can accelerate the process with urban construction, sewage discharges, agricultural practices, and residential development (Minnesota MPCA, 2008).

Impact on Water Quality

Nitrogen & Phosphorus causes severe nuisance algal blooms yield unpleasant odour and appearance that reduce the aesthetic appeal of lakes. This may result in declines in fishing and swimming and hurt tourism (EPA Report).

As algae die and decompose, the process consumes oxygen. Submerged plants without sunlight die, decompose and consume more oxygen. Without enough dissolved oxygen in the water, fish and other organisms suffer and die because they can't breathe (Minnesota MPCA, 2008). This can occur locally or much farther downstream leading to degraded estuaries, lakes and reservoirs. For example, fish and other aquatic life can no longer survive in the river so called “dead zone”.

Conclusion

It is anticipated that an increasing number of WWTPs would be required to achieve nutrient removal in order to protect the river water bodies. The BNR process is a proven method of removing nutrients using naturally occurring microorganisms. The primary objective of BNR plant operations is to achieve regulatory compliance consistently. Other objectives often include operational cost savings, process optimization, safe and clean workplace. Meeting these objectives demands proper design, operation, and management (Jeyanayagam, 2005). Designers should incorporate features that would provide maximum process flexibility and ease of operation and maintenance

The BNR process is mediated by several functional groups and is more complex than a secondary system. More than ever before, we are getting closer to understanding the competing and complimenting reactions at a microbial level (Marta et al.).

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