Parameters influencing Nitrite generation in drinking water MBBR Denitrification

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ABSTRACT

Biological denitrification of contaminated drinking water is a promising and cost effective treatment method. A central challenge in biological nitrate removal is incomplete denitrification, and a concomitant production of nitrites (NO_2). Since nitrites are considered more dangerous for human consumption than nitrates (NO_3), restrictions on allowable nitrite concentrations are substantially more severe than on nitrate, thereby greatly complicating the purification challenge (Kim Shapiro et al., EPA 2007).

The objective of this study was to use a Moving Bed Biofilm Reactor (MBBR) in a biological denitrification process that consistently meets nitrate drinking water requirements while also minimizing nitrite production. Drinking water contaminated with nitrate was treated in a 10-month bench scale pilot test involving an anoxic denitrification stage followed by an aerobic polishing stage. The subsequent full-scale pilot system treated well water with a nitrate level of ca. 120 mg NO_3/l and consisted of only an anoxic stage followed by complementary physical filtration stage.

Nitrate load; the carbon source used (ethanol & citric acid); temperature and HRT were each evaluated for their influence on effectiveness of nitrate removal rates and on nitrite production. The correlation between parameters such as Dissolved Oxygen (DO), ORP levels and the acclimation period was also studied. Results showed that the nitrate removal rates were higher and nitrite production was completely absent with the use of ethanol when compared to citric acid. Nitrate removal rates increased further with increasing temperatures. Good correlation was found between nitrite levels and operational parameters such as DO, ORP and acclimation period. Nitrate *and* nitrite concentrations in treated water met stringent regulations.

KEY WORDS

Biomass carriers, Carbon source, Denitrification, Drinking Water, MBBR, Nitrate, Nitrite

INTRODUCTION

There are two main sources of nitrate contamination of drinking water: Chemical crop fertilizers and improper disposal of human and animal wastes.

While the common methods for nitrate removal in drinking water are physico-chemical methods such as Ion exchange, Reverse Osmosis and Electrodialysis, the main disadvantage of all these technologies is that a brine or backwash waste stream is generated and needs to be disposed of. These streams contain a high nitrate concentration that needs to be further treated.

Biological treatment, on the other hand, offers an attractive solution for nitrate contaminated water since the nitrate is converted to nitrogen gas (N_2), and therefore no brine or backwash stream is generated.

The biological process, used in this study, consisted of a Moving Bed Biofilm Reactor (MBBR), using Aqwise Biomass Carriers (ABC5).

The first stage of the research was performed in a bench scale unit, in order to derive design parameters and to define the conditions needed to eliminate an incomplete denitrification process with nitrite production. In addition, it was used to quantify denitrification rates. Based on the results obtained from the bench scale pilot, a full scale project was conducted with higher flow rates, treating well water containing high Nitrate level.

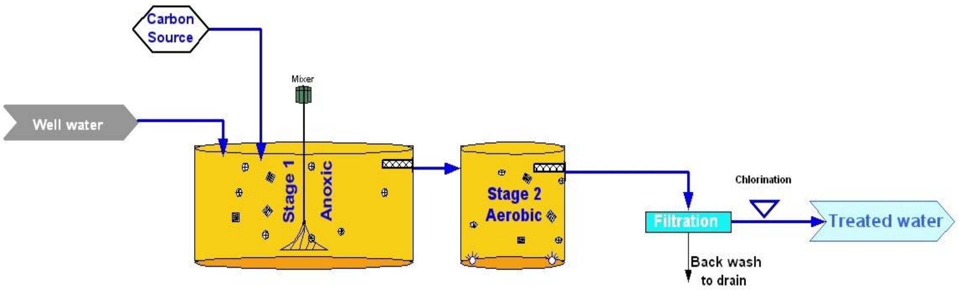
PILOT UNIT DESCIPTION

Figure 1 depicts the experimental bench scale pilot unit. The pilot unit consisted of an anoxic stage to which the carbon source was added and nitrate removal was achieved, followed by an aerobic stage for removal of carbon residues from the treated water. The full scale pilot plant did not include the aerobic stage.

During the piloting period, the system was operated at different temperatures and with different carbon sources. The influence of these parameters on the denitrification rates and nitrite production was evaluated.

From the pilot plant data the influence of operation parameters such as HRT, DO and ORP on the nitrite level was also evaluated.

Figure 1 - Schematic of the pilot unit



RESULTS AND DISCUSSION

As demonstrated in figure 2, the denitrification process is influenced by the temperature. Same phenomenon was observed by Amatya I.M et al (2005). At higher temperatures the nitrate removal is higher and the denitrification reaction is complete, resulting in very little, if any, nitrite generation.

Since the aim was to remove nitrate from drinking water, only food grade carbon sources can be used. The two carbon sources used were the citric acid and ethanol.
The influence of the carbon source on denitrification rates and Nitrite generation is demonstrated in figure 3.

Figure 2 - Effect of temperature on Nitrate concentrations and Nitrite generation during denitrification process (Citric acid as carbon source)

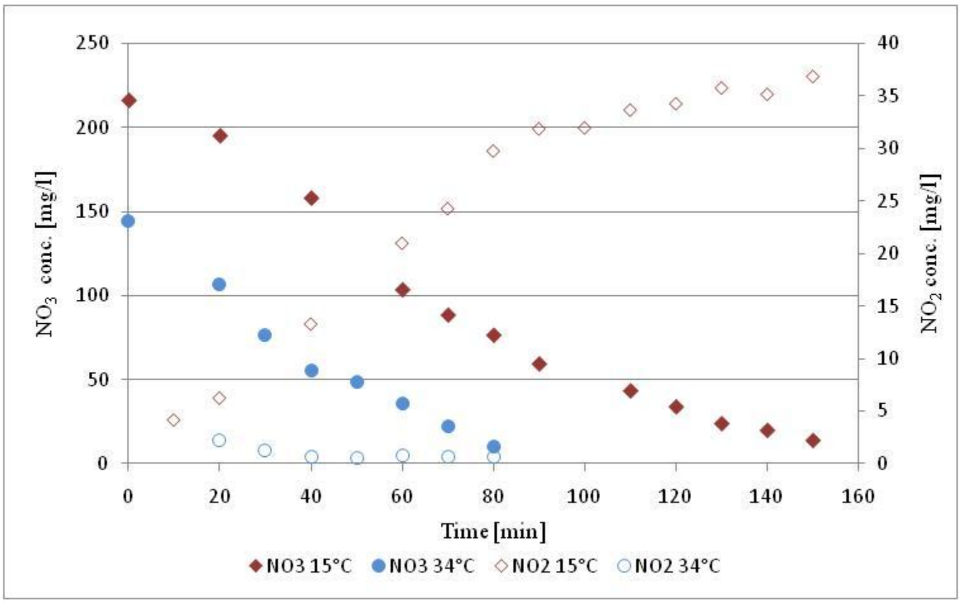
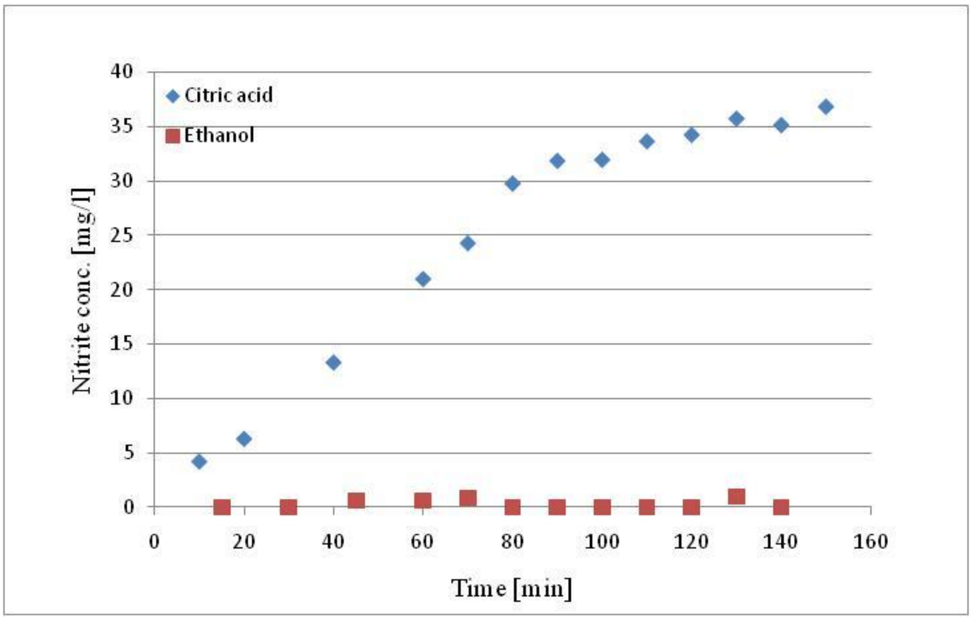


Figure 3 - Influence of carbon source on Nitrite generation (15°C)



The maximum acceptable level for Nitrite in drinking water is 3 mg/l. Figure 3 present the results obtained for Nitrite generation for both carbon sources at temperature of 15°C. As can be seen from the data, using Ethanol as the carbon source resulted in complete denitrification process with very low Nitrite concentration, if any. At the same time, using Citric acid as the carbon source at the same temperature caused Nitrite generation to a level exceeding the maximum level permitted by the regulations. The results are in consistent with those reported by Kesseru et al (2003) and Assayamy et al. (2007).
The same phenomena were found for other temperatures, with less significant differences between the different carbon sources.

Figure 4 exhibit the relations between ORP and the nitrite generation. At negative ORP values, the system tends to be oxidized by reduction of nitrate to gain nitrogen gas, therefore the nitrite concentration are very low.

Figure 4 - Influence of Nitrate load on Nitrite generation

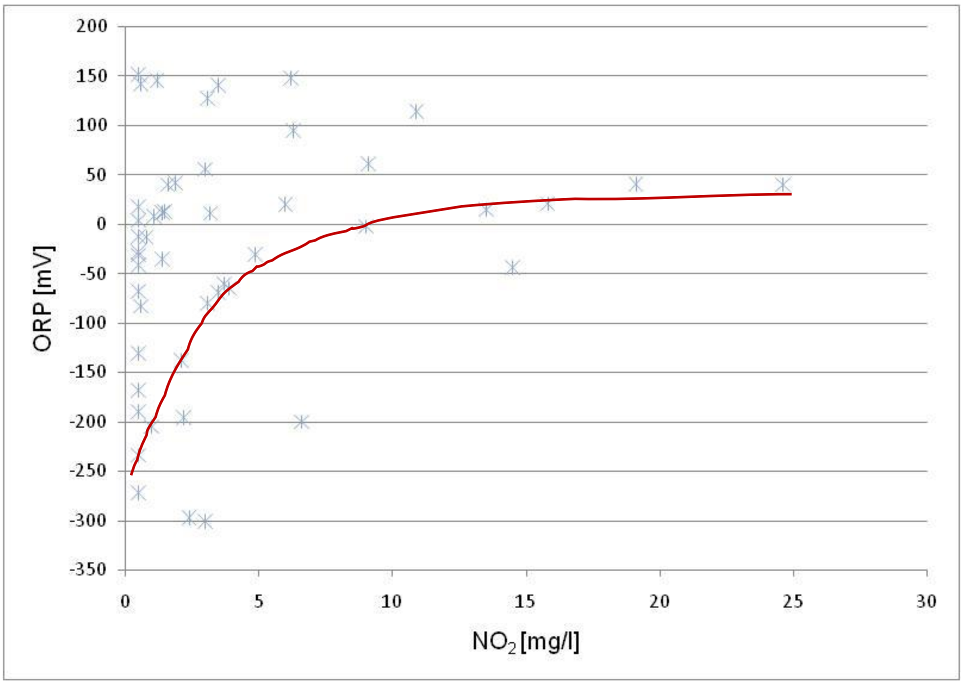
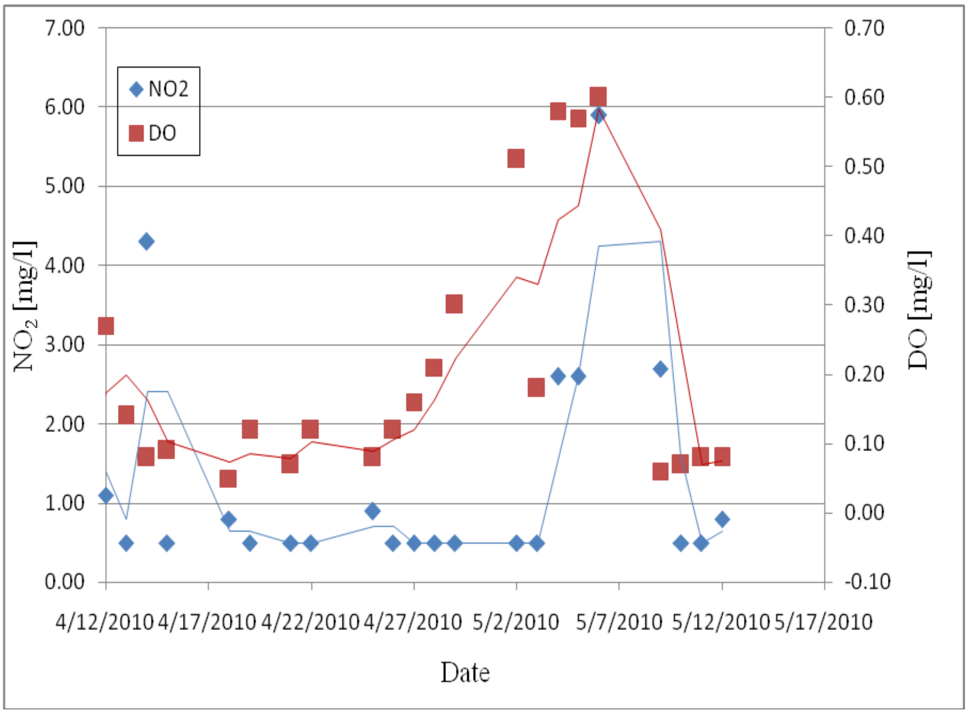


Figure 5 - Correlation between Dissolve Oxygen concentrations and nitrite generation



Since denitrification is the conversion of nitrate (NO_3^-) to nitrogen gas (N_2) by bacteria in absence of oxygen (O_2), it is very important to keep the DO concentrations in the anoxic reactor very low. As shown in figure 5, at DO concentrations as low as 0.6 mg/l, nitrite concentrations above the standard requirements (3 mg/l) were generated.

The results of the current study were used to design a pilot system for higher flow rates. Levels of nitrite measured in the system under different operational conditions – e.g., HRT, Carbon Source, process temperature and dissolved oxygen levels – were used as an indication of the range of these design parameters to be applied in design of full scale MBBR systems for denitrification of drinking water.

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