NITRITE INHIBITION ON PHOSPHORUS UPTAKE RATE: THE EFFECT OF PH

Dimitris Andreadakis[1], Gerasimos Fragkiskatos[1], Kyriaki Argyropoulou[1], Constantinos Noutsopoulos[1], Simos Malamis[1] and Daniel Mamais[1]

[1]Sanitary Engineering Laboratory, Department of Water Resources and Environmental Engineering, School of Civil Engineering, National Technical University of Athens, Athens, Greece

Corresponding author email: andreadakisdimitris@gmail.com

ABSTRACT

Background information

The removal of phosphorus and nitrogen from wastewater is vital to the prevention of eutrophication. Enhanced biological phosphorus removal (EBPR) is considered an economical and effective method for phosphorus removal and is widely applied in many wastewater treatment plants (WWTPs). Reject water produced during the processing of sewage sludge contains high nutrient concentrations and its recirculation to the inlet of the WWTP can increase nutrient loading by 10-30%. Therefore, the side stream treatment of reject water is an attractive option. Due to the high concentrations of ammonium nitrogen and thus free ammonia in reject water, the inhibition of nitrite oxidizing bacteria (NOB) makes nitrogen removal via conventional nitrification/denitrification rather impossible. Nitrogen removal via nitration/denitration has the added advantage of lower COD and oxygen requirements and decreased sludge production. However there are studies reporting on the adverse effect of nitrite on the EBPR (Meinhold et al., 1999). The degree to which phosphorous removal is inhibited by nitrite varies significantly in each study and is likely attributed to differences in microbial acclimation. Recent studies have suggested that free nitrous acid (FNA), the protonated form of nitrite is the actual inhibitor rather than the nitrite anion (Zhou et al., 2012). Therefore the inhibitory effects of nitrite on EBPR seem to be strongly pH dependant. The objective of this study was to evaluate the effect of nitrite on aerobic phosphorous uptake rate (PUR) at different pH levels.

Materials and methods

A 10L laboratory-scale sequencing batch reactor (SBR) was used to cultivate polyphosphate accumulated organisms (PAOs)-enriched sludge. The SBR was operated with two cycles per day, each consisting of an anaerobic phase followed by an aerobic phase and an anoxic phase. Settling and decanting occurred once a day. The solids retention time (SRT) was 10 d, while the hydraulic retention time (HRT) was 2d. Feed consisting of synthetic wastewater took place at the start of each anaerobic and anoxic phase. Once stable conditions were achieved, a series of ex-situ batch experiments focused on the aerobic PUR were conducted on sludge retrieved from the SBR. For each experiment, the sludge was divided into 3 bioreactors, one serving as a control and duplicates for a specific nitrite concentration. The reactors were then spiked with a sufficient amount of acetate and phosphorous and left under anaerobic conditions for 1 hour before the commencement of a 4 hour aerobic operation. pH was kept stable during the experiment with the frequent addition of sulphuric acid 0.1 N. The parameters measured were temperature, pH, DO, ORP, TSS, VSS, MLSS, MLVSS, PO_4-P and NO_2-N. All analyses of SBR unit and batch assays were performed in accordance with Standard Methods(APHA, 2012).

Main results

The operation of the SBR unit can be divided into 3 phases. During the first phase the inhibitory effect of nitrite on PUR was studied for the pH values of 7 and 8. Accordingly during the second phase of the experiments the inhibitory effect of nitrite on PUR at a pH of 7.5 was investigated. In the third phase following a reset of the SBR unit experiments were implemented at pH values of 7.5. Figure 1 illustrates the effect of nitrite and more specifically its protonated form FNA on PUR biomass activity at three

different pH values (7, 7.5, 8). According to the results the control PUR (experiments under the absence of nitrite) during the three periods varied considerably at values between 3.8 - 10.9 mgP/grVSS-h for the first phase, 3.9 - 17.6 mgP/grVSS-h for the second phase and between 4.6 – 8 mgP/grVSS-h for the third phase. The increase in PUR in control experiments recorded during the second phase was followed by an increase in the inhibition level of nitrite on biomass activity with respect to phosphorus removal (PUR), thus highlighting the sifting of biomass community. Total inhibition of PUR was observed at a nitrite concentration of 300 mg/L (0.013 mg FNA/L) at a pH value of 8, while the respective value at the pH of 7 was equal to 50 mg/L (0.007 mg FNA/L). Accordingly 50% inhibition on PUR was achieved for nitrite nitrogen concentrations of 10 mg/L (0.0027 mg FNA/L) and 50 mg/L (0.0013 mg FNA/L) at pH values of 7 and 8 respectively. Interestingly enough the inhibition of PUR at the pH of 7.5 was close to that at pH of 8 for moderate NFA concentrations, whereas much higher (comparable to the ones at the pH of 7) at higher NFA concentrations. For the pH value of 7.5, 50% inhibition on PUR was achieved for a nitrite concentration of 30 mg/L (0.0024 mgFNA/L).

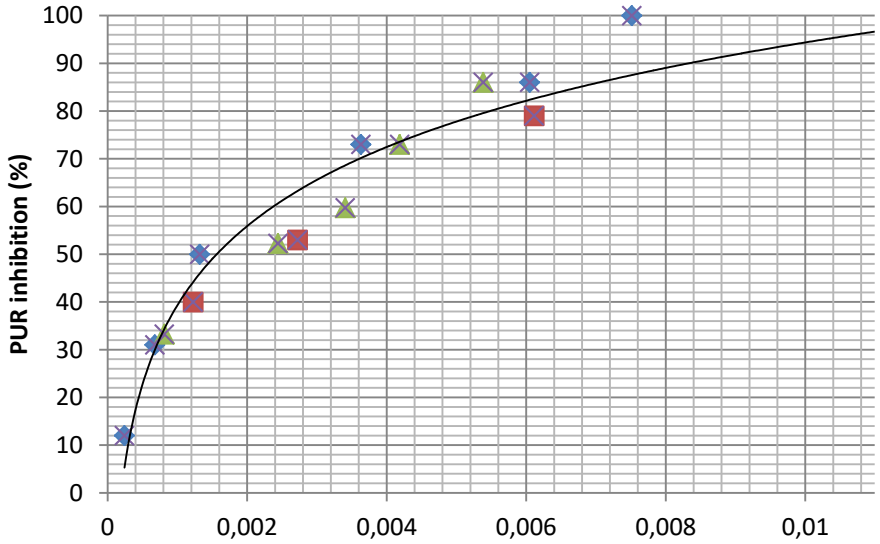

Figure 1. The effect of FNA on PUR inhibition at three pH values

Conclusions

The inhibitory effects of nitrite on EBPR are highly dependent on microbial acclimation. Interestingly, when high PUR are achieved, nitrite induced inhibition appears greater. Inhibition increases inversely to pH and free nitrous acid appears to be the main inhibitory factor. 50% inhibition on PUR was observed for NO_2-N concentrations of 10, 30 and 50 mg/L at pH values of 7, 7.5 and 8 respectively.

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References:

Meinhold, J., Arnold E., Isaacs S. "Effect of nitrite on anoxic phosphate uptake in biological phosphorus removal activated sludge", *Water Research., 33: 1871-1883 (1999).*

Zhou Y., Ganda L., Lim M., Yuan Z., Ng W.G. "Response of poly-phosphate accumulating organisms to free nitrous acid inhibition under anoxic and aerobic conditions", *Bioresource Technology 116: 340–347 (2012)*

American Puplic Health Association (2012).Standard Methods for Examination of Waters and Wastewaters, 22nd ed., Washington D.C, 2012.