

## A distillery by-product as an external carbon source for enhancing denitrification in mainstream and sidestream treatment processes

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### Background

The efficiency of denitrification in biological nutrient removal (BNR) activated sludge systems is strongly dependent on the availability of appropriate carbon sources. In order to enhance the process within the existing capacities, the simplest solution is to add external carbon sources to anoxic compartments. There is a number of effective, commercially available and organic compounds (such as methanol, ethanol, acetic acid, sodium acetate and glucose) which can be categorized as the “conventional” carbon sources. Primarily due to high costs of those compounds, various industrial by-products or waste materials have recently received more attention as the “*alternative*” external carbon sources, but their full-scale applications have been less documented.

In the paper presented at the previous WEF/IWA Nutrient Removal Conference (Makinia et al., 2009), the effects of dosing different organic compounds (settled wastewater, and various external “conventional” and “alternative” carbon sources) on the denitrification capability and EBPR interactions were compared using a full-scale process biomass from the “Wschod” WWTP in Gdansk (Poland). Fusel oil was identified as an interesting “alternative” carbon source as the observed nitrate utilization rates (NURs) with the support of fusel oil were higher in comparison with ethanol and methanol. Fusel oil is a by-product of the distillation of ethyl alcohol and contains mainly amyl alcohols, other alcohols, acids, esters and aldehydes. In the literature, there have been several studies reporting a successful use of fusel oil for enhancing denitrification. For example, in the early study of Monteith et al. (1980), the average value from 30 NUR measurements with fusel oil was 13.8 g N/(kg VSS·h), approximately 6 times greater compared to the values obtained in the parallel experiments with methanol.

This paper presents preliminary results of a 3-year project concerning the use of fusel oil as a carbon source for denitrification in the mainstream and sidestream treatment processes. The project is carried out in cooperation with the Water Environment Research Foundation (WERF) Nutrient Removal Challenge Program and ultimately aims at transferring the results of lab-scale and pilot-scale investigations to full-scale applications. In comparison with the previous lab experiments (Makinia et al., 2009), the new investigations also focus on the NO<sub>2</sub>-N behavior and the potential of using fusel oil for reject water treatment in a sequencing batch reactor (SBR).

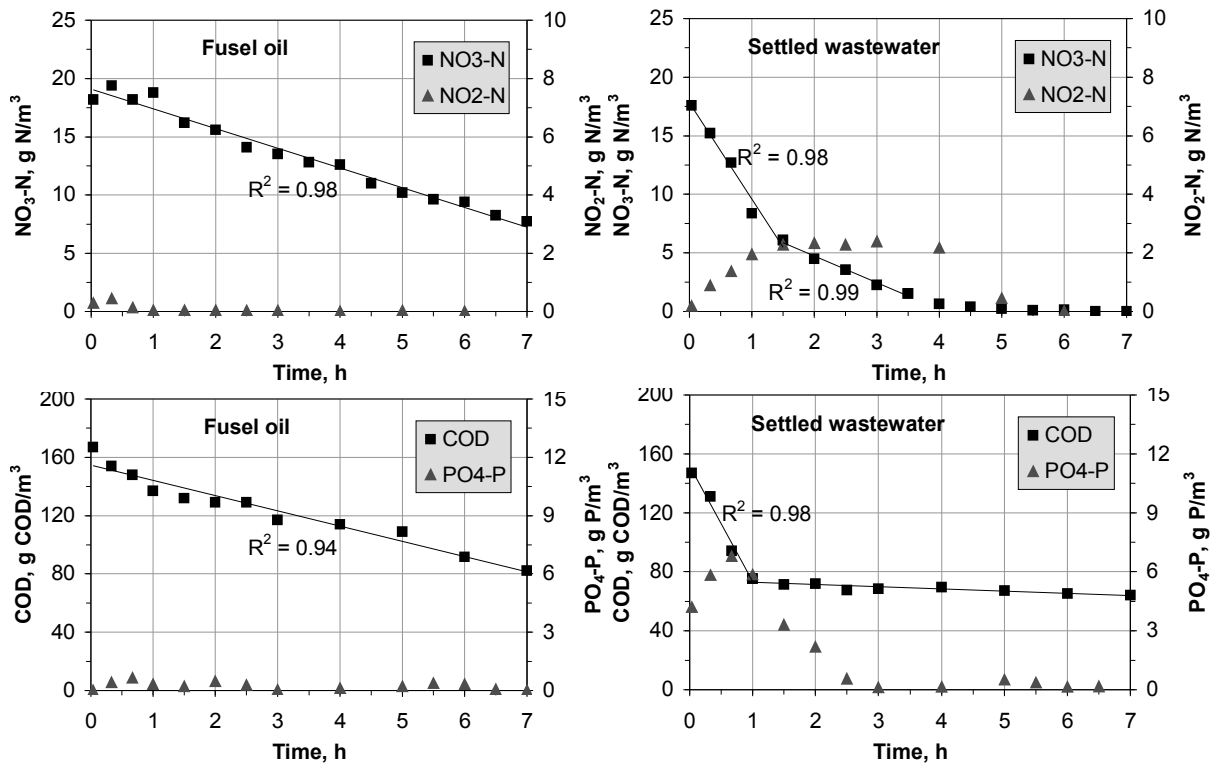
### Material and methods

Three kinds of batch experiments, including the “conventional” denitrification, denitrification preceded by an anaerobic phase and oxygen uptake rate (OUR) measurements, were carried out with samples of fusel oil originating from two local distilleries and non-acclimated process biomass. For comparison, other carbon sources, such as settled wastewater, ethanol and acetic acid, were also used in similar experiments in a parallel batch reactor. Samples of the mixed liquor were frequently analyzed for NO<sub>3</sub>-N, NO<sub>2</sub>-N, PO<sub>4</sub>-P and COD. In the experiments with reject water, two batch reactors were operated in a sequencing “fill-and-draw” mode for two weeks (12-hour nitrification phase, 11-hour denitrification phase, 1-hour settling and decantation). In each cycle, a new portion of reject water was added in the amount of 10-30% of the reactor volume.

### Results and significance of the findings

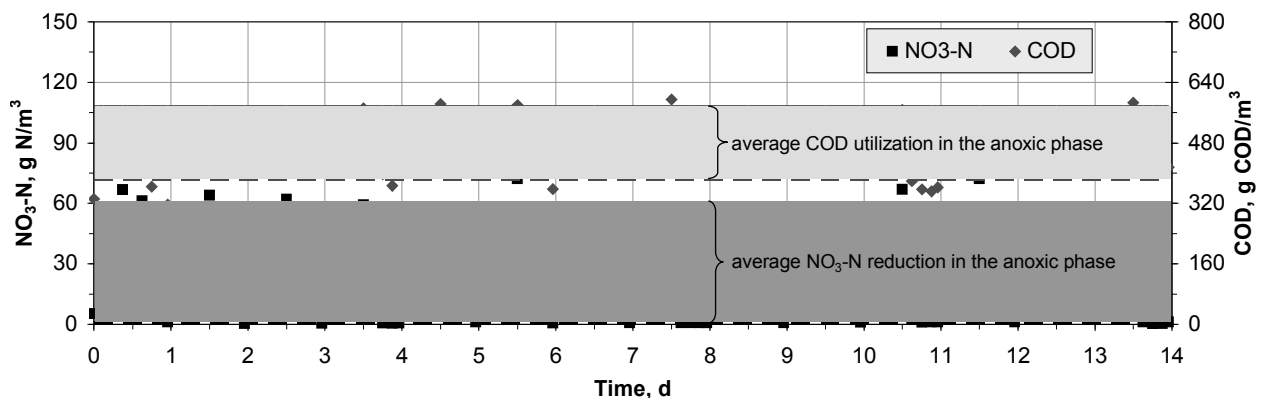
In the batch experiments with fusel oil, the observed NURs, COD/N ratios and yield coefficients were similar to the results obtained with ethanol. Moreover, only minor effects of these carbon sources on the behavior of NO<sub>2</sub>-N and PO<sub>4</sub>-P were observed in the conventional denitrification

tests (Figure 1). For comparison,  $\text{NO}_2\text{-N}$  and  $\text{PO}_4\text{-P}$  were apparently released during the experiments with wastewater until the readily biodegradable fraction was present (Figure 1).



**Figure 1.** Sample results of the NUR measurements with fusel oil and settled wastewater in the batch reactors

Initial batch tests with reject water revealed that nitrification was completely inhibited when the reject water occupied 50% of the reactor volume, whereas no inhibition was observed at the dose of reject water of 10% of the reactor volume (data not shown). During the operation of the SBR treating reject water, the addition of fusel oil supported efficient denitrification. The reduction of  $\text{NO}_3\text{-N}$  was primarily occurring within the initial 3 hours of the anoxic phase at a relatively low COD/N ratio ( $\approx 3.3$ ) without considering  $\text{NO}_2\text{-N}$  which were detected (up to 30 g  $\text{NO}_2\text{-N}/\text{m}^3$ ) at the end of the aerobic phase in the second week of the experiment.



**Figure 2.** Effects of the addition of fusel oil to a lab-scale SBR treating reject water in the conventional nitrification-denitrification process

## References

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- Monteith, H. D., Bridle, T. R. and Suthon, P. M. (1980). Industrial waste carbon sources for biological denitrification. *Prog. Water Technol.*, 12 (6), 127-141.