THE IMPACT OF PRECIPITATION & EXTERNAL C SOURCE ADDITION ON BIOLOGICAL NUTRIENT REMOVAL IN ACTIVATED SLUDGE SYSTEMS - EXPERIMENTAL INVESTIGATION & MATHEMATICAL MODELING

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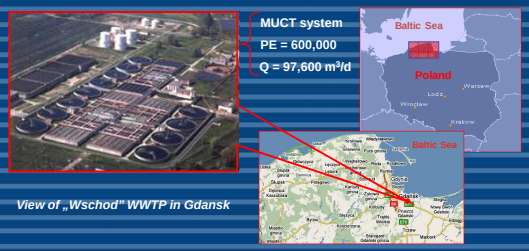
INTRODUCTION

In modern biological nutrient removal (BNR) activated sludge systems for combined N/P removal, sufficient amounts of organic carbon should be ensured for denitrification and enhanced biological phosphorus removal (EBPR). Due to high costs of the commercial compounds and acclimation periods (usually) required, the effective use of internal (slowly biodegradable) carbon sources is preferred. Moreover, various industrial by-products or waste materials have recently received more to their high C/N ratios and high content of readily biodegradable organic fraction (Figure 1).

The aim of this study was to determine the effects of chemical precipitation and addition of external carbon sources on the denitrification capability and EBPR interactions at the "Wschod" WWTP (600,000 PE) in Gdansk (Figure 2). Different kinds of tests were carried out with the settled wastewater (without pretreatment and after coagulation-flocculation) and external carbon sources (ethanol and fusel oil). The experimental investigations were supported by both lab-scale and full-scale simulations using a newly developed model as an expansion ASM2d (Figure 3).

Figure 1. The different carbon (C) sources in WWTPs



View of „Wschod" WWTP in Gdansk

Figure 2. Localisation of the studied plant

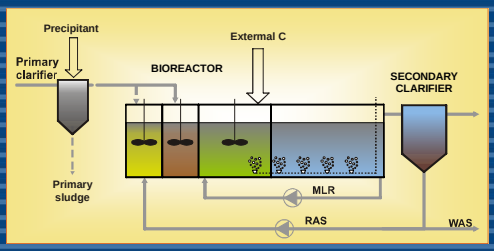


Figure 3. Internal substrates flows in BNR activated sludge systems

RESULTS AND DISCUSSION

Batch experiments with non-acclimated biomass

The removal of colloidal and particulate fractions resulted in the reduced process rates (observed in the batch tests), such as denitrification, phosphate release and phosphate uptake (under aerobic and anoxic conditions). The reduction ranged from approximately 30% for the NUR during the "conventional" NUR measurements, up to 70% for the P uptake during the anoxic phosphate utilization rate (PUR) measurement.

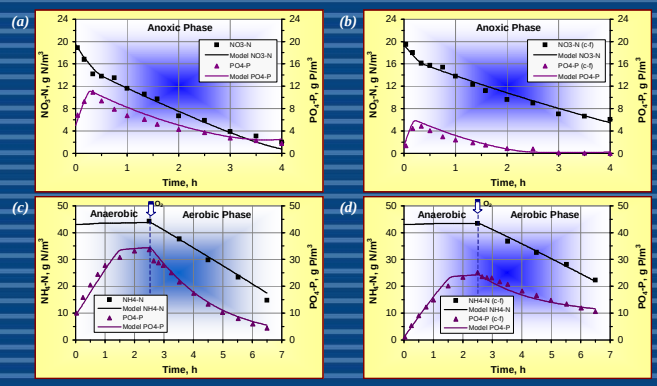


Figure 4. Measured data vs. model predictions in the batch experiments with the settled wastewater with and without pre-treatment: (a-b) NO_3-N and PO_4-P in the conventional NUR measurements, (c-d) NH_4-N and PO_4-P in the PRR and aerobic PUR measurements

With the calibrated ASM2d, the principal process rates (P release rate, anoxic/aerobic P utilization rate, ammonia utilization rate and NUR) were accurately predicted also in one- and two-phase batch tests with the pretreated settled wastewater (Figure 4).

The expanded ASM2d was calibrated using the results of a series of batch tests with the process biomass and external carbon sources. In the NUR measurements with either ethanol or fusel oil, there was no significant PO_4-P released to indicate anaerobic consumption of these substrates by PAOs (Figure 5a). For comparison, PO_4-P was released during similar experiments with the settled wastewater until the readily biodegradable substrate was present in the batch reactor (Figure 4a-b).

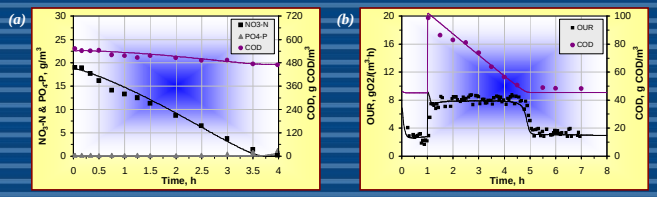


Figure 5. Measured data vs. model predictions in the batch experiments with the process biomass and ethanol: (a) NO_3-N, PO_4-P and COD in the "conventional" NUR test, and (b) OUR and COD in the "conventional" OUR test

The expanded ASM2d was also capable of simulating the conventional OUR measurements with ethanol (Figure 5b).

Full-scale measurement campaign

Figure 6 shows variations of the influent flow rate and COD (total and soluble) observed during the 4-day measurement campaign. The influent flow rate revealed a typical daily pattern with the peak values below 30,000 m³/d (minimum) and over 130,000 m³/d (maximum). The average total COD was 699 (±90) g COD/m³. With the maximum peak reaching 1000 g COD/m³. The soluble COD, determined with the method of Mamais et al. (1993), was relatively stable over the entire campaign with the average value of 238 (±22) g COD/m³.

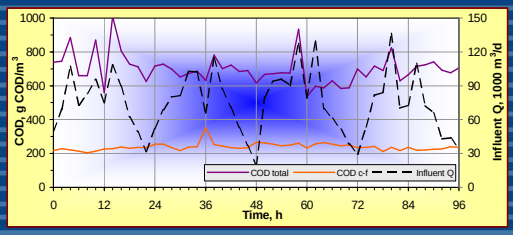


Figure 6. Variations in the influent flow rate and COD (total and soluble) during the 4-day measurement campaign in the full-scale MUCT bioreactor

In order to examine the effect of precipitation, full-scale simulations were run for the following scenarios (Figure 7):

- the reference case (no precipitation and no external carbon addition),
- the effect of precipitation (XCOD and soluble P removed in 90%) with no external carbon addition,
- the effect of precipitation (XCOD and soluble P removed in 90%,) and external carbon addition (2 m³/d of $S_{A,1}$ having the concentration of 1,600,000 g COD/m³).

With the calibrated ASM2d expansion, behaviors of NH_4-N (data not shown), NO_3-N and PO_4-P (Figure 7) in the full-scale MUCT bioreactors were matched accurately by the model predictions. In scenario 2, precipitation significantly affected denitrification as the average effluent NO_3-N concentration increased from 6.8 g N/m³ to 14.3 g N/m³. Simultaneously, the average anaerobic PO_4-P concentration dropped from 41.6 g P/m³ to 25.5 g P/m³. The addition of external carbon source (scenario 3) recovered denitrification to the level comparable to the reference case (effluent NO_3-N = 6.9 g N/m³), while PO_4-P was almost completely utilized in the anoxic compartment. Precipitation and external carbon addition had hardly any effects on behavior of NH_4-N (data not shown).

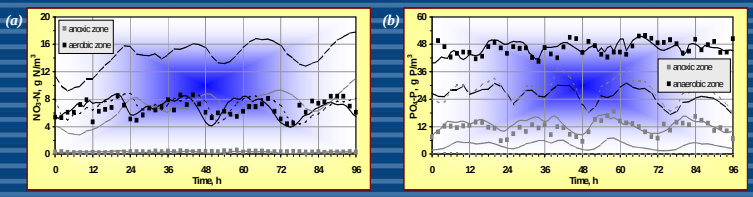


Figure 7. Measured data vs. model predictions for a 4-day measurement campaign in the full-scale MUCT bioreactor: (a) NO_3-N concentrations in the anoxic and aerobic zone effluents, (b) PO_4-P concentrations in the anaerobic and anoxic zone effluents (solid lines – predictions of the reference case, dashed lines – predicted effects of precipitation, dotted lines – predicted effects of precipitation and addition of external carbon)

CONCLUSIONS

- Precipitation of colloidal and particulate organic fractions has a significant effect on denitrification and EBPR. The removal of these two fractions by coagulation-flocculation resulted in the reduced process rates (to a variable extend).
- An expansion of ASM2d accurately predicted the effects of precipitation and external carbon addition in batch experiments. Full-scale simulations revealed that addition of external carbon source can compensate the effects of precipitation resulting in a similar NO_3-N behavior compared to the reference case (without precipitation and external carbon addition). The combined effects of precipitation and addition of external carbon source resulted in a significantly different PO_4-P behavior compared to the reference case.

ACKNOWLEDGEMENTS

INNOVATIVE ECONOMY
NATIONAL COHESION STRATEGY

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