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Autotrophic nitrogen removal for decentralized treatment of industrial textile wastewater: process stabilization and modelling

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Abstract: In recent years, single-stage partial nitritation/anammox process emerged as a sustainable solution for nitrogen removal from industrial wastewater. However, the process application often requires case-specific adaptation. In the present study, process application as a decentralized treatment to digital textile printing wastewater was assessed. The biomass was inoculated in a lab-scale reactor and progressively acclimated until reaching the target loading rate. The experimental campaign was characterized by the occurrence of biomass inhibition phenomena causing process instability. At quasi-stable conditions, total nitrogen removal was 70%, in compliance with regulations on discharge in the public sewage (100 mg_N/L). After proper calibration, process modelling could effectively describe experimental data, also indicating its importance for process monitoring and control practices.

Keywords: decentralized wastewater treatment; industrial wastewater; nutrient removal.

Introduction

Many industrial activities discharge wastewater that municipal wastewater treatment plant (WWTPs) can hardly treat. This is the case of digital textile printing (DTP), a wide spreading technology (GIA, 2018). Rinsing baths after DTP have a low COD/N ratio due to high concentrations of organic nitrogen (urea) and ammonium, coupled to dyes and other organic pollutants.

Among emerging technologies, autotrophic nitrogen removal by anammox bacteria represents a promising solution to lower the nitrogen content in such industrial wastewater (Lackner et al., 2014) and reducing the unbalanced COD/N ratio for further treatment in municipal WWTPs. However, besides numerous benefits, the application of anammox bacteria combined with partial nitritation in a single-stage process (PN/anammox) is often complicated by variable wastewater characteristics and inhibition phenomena (Li et al., 2018).

The present study was carried out within the framework of EU LIFE DeNTreat project (https://www.life-dentreat.eu/). The treatment of digital textile printing wastewater from Como textile district, in Italy, was assessed at lab-scale in the view of the decentralized full-scale application of PN/anammox process for reducing total nitrogen content and meeting regulatory limit on discharge in the public sewage (100 mgN/L). In addition, the dynamic modelling of the biological process allowed a better understanding of process mechanisms and provided an explanation for experimental observations.

Materials and methods

The lab-scale reactor, as described in Bellandi et al. (2019), is a 2-L sequencing batch reactor (SBR), inoculated with biomass from Paques (Balk, The Netherlands). During the start-up, the reactor was fed with synthetic wastewater. The ratio of industrial textile wastewater was progressively increased, until feeding with undiluted batches.

Process modelling was performed using the tool dedicated to sequential reactors with granular biomass (Granular Sludge Sequencing Tank, GSST) of the software BioWin (EnviroSim), whose development was based on work by Takács et al. (2007).

Results and conclusions

The characteristics of industrial textile wastewater collected from industry equalization tank are reported in Table 1. The nitrogen content was relevant, with remarkable variability over time, and already partially ammonified (around 75%), probably due to biochemical phenomena occurring in the equalization tank (biological ureolysis). The ratio between the biodegradable fraction of COD and total nitrogen was around 2, fit for the application of the PN/anammox process.

Experimental data from lab-scale reactor are shown in Figure 1, in which feeding conditions of the synthetic medium and the wastewater are detailed. The importance of an acclimation period was observed. In particular, significant reversible reductions in bacterial activity were observed when industrial textile wastewater ratio was increased, probably due to wastewater toxicity. Quasi-stable conditions in the first part of start-up phase were achieved after about 110 days. Afterwards, a pH-probe failure resulted in a wrong pH adjustment by the reactor control system and led to a considerable rise of pH values (well above 8) and a sudden drop in bacterial activity. In the second part of experimental campaign, biomass was reinoculated for a quick system restart, and the effects of different batches of industrial textile wastewater was evidenced. A drop in bacterial activity was observed, this time probably caused by inhibiting compounds. However, on average, 70% removal on total nitrogen was achieved, leading to effluent concentration of about 50 mg/L, well fit for discharge into the public sewerage.

In the second part of the experimental campaign, process modelling applied to experimental data, collected in a period of 30 days, gave the results shown in Figure 2. After calibration, experimental data showed a reasonably good fitting, indicating the importance of a case-specific adaptation of kinetic parameters in order to account for wastewater characteristics. Biofilm profile in granules along experimental campaign was simulated and predictions were confirmed by microbiological analysis.

In conclusion, the present work demonstrated the effective application of PN/anammox for treating digital textile printing wastewater, although process instability due to process operating conditions and wastewater characteristics was clearly evidenced, possibly resulting in a occasional process failure. Therefore, the importance of careful process monitoring and control, supported by modelling, was highlighted.

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Table 1. Characteristics (mean ± st.dev.) of the synthetic solution and the industrial textile wastewater (WW).

	Synthetic solution [mg/L]	WW [mg/L]
COD	0 ± 0	716 ± 91
NH_4-N	154 ± 5	177 ± 32
NO_3-N	0 ± 0	0.6 ± 0.4
NO_2-N	0 ± 0	0 ± 0
Total Nitrogen	154 ± 5	223 ± 30

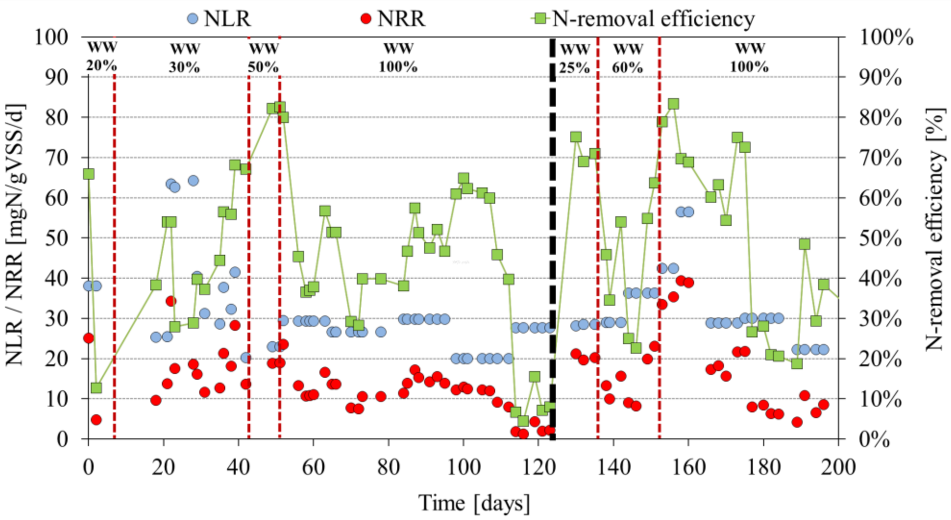

Figure 1 Main nitrogen indicators, namely nitrogen loading rate (NLR), nitrogen removal rate (NRR) and nitrogen removal efficiency, in lab-scale PN/anammox reactor during the experimental campaign with the industrial textile wastewater (WW) mixed with synthetic medium at different concentrations.

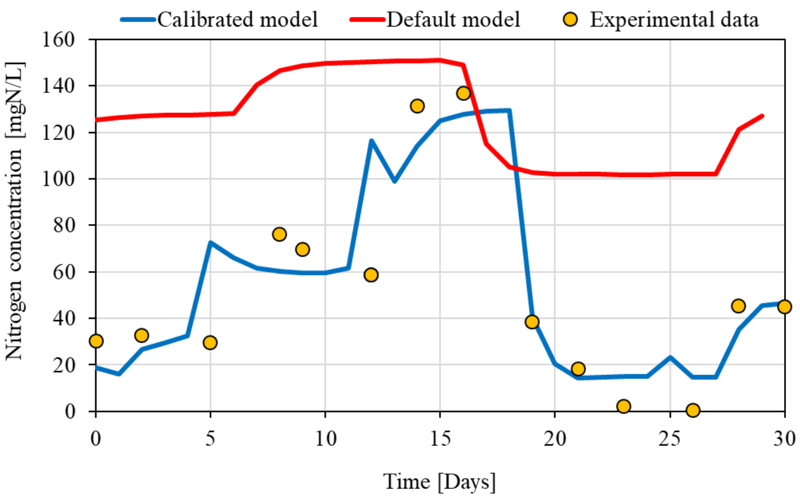

Figure 2. Process modelling results.