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Influence of industrial discharges on the performance and population of a biological nutrient removal process

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Abstract

The study described here concerns the influence of long-term industrial discharges on a biological nutrient removal process. The effects of such discharges were modeled and the effect on the effluent quality and on the population of activated sludge was evaluated. The influent wastewaters used, i.e., urban sewage and industrial discharges, were real wastewaters. A model of the process involving GAO integrated into ASM2d was used for the simulations. For the simulation of the industrial discharges only two parameters needed to be changed and these were the maximum fermentation rate (q_{fe}) and the reduction factor for anoxic activity of PAO (η_{NO_3}). These changes could be explained in terms of the high biodegradability and the absence of toxic compounds in the studied wastewaters. The industrial discharges were found to have either a positive or negative impact on the nutrient and COD removal. The level of impact was found to depend on the characteristics of the discharge—mainly the VFA, the nitrogen content and the P/COD ratio.

Keywords: Bioreactors; Activated sludge; Modeling; Waste-water treatment; Biological nutrient removal; Environmental preservation

1. Introduction

The approval of Directive 91/271CE, which limits the concentration of nutrients (N and P) in treated wastewater discharges, has led the majority of Waste Water Treatment Plants (WWTP) in Europe to work with nutrient removal processes.

Biological nutrient removal (BNR) processes are complex due to the diversity of the substrates and microorganisms involved. These processes are mainly based on the removal of nitrogen by nitrification–denitrification coupled with a biological phosphorus removal (BPR) process. Given the nature of these processes it is necessary to set up at least three different environments (anaerobic, anoxic and aerobic).

The most important processes occurring in these environments are as follows: (i) in the anaerobic zone volatile fatty acids (VFA) are stored by phosphate accumulating organisms (PAO) [1,2], including the fraction termed denitrifying phosphate accumulating organisms (DNPAO) [3,4], and by glycogen accumulating organisms (GAO) [4–6]; (ii) in the anoxic zone denitrifying organisms use nitrate as an electron acceptor and DNPAO takes up phosphorus using nitrate as the electron acceptor [7,8]; (iii) finally, in the aerobic zone ammonia nitrogen is nitrified by nitrifiers, phosphorus is taken up by PAO, and COD is mainly consumed by heterotrophic organisms [9].

The WWTP for BNR are usually optimised to remove nutrients from urban sewage, but in some cases a significant supply of industrial wastewater can modify the composition of the influent wastewater. Although such industrial discharges have hardly been studied, they can cause numerous changes related to the effluent quality – mainly with regard to phosphorus and nitrogen removal – and to the microbial population present in the biological reactor.

The relative population of the microorganisms of the activated sludge is complex [3,10] and depends on the characteristics of the influent wastewater—mainly on the readily biodegradable COD (RBCOD), VFA, phosphorus and nitrogen contents. Competition for the VFA occurs when PAO, GAO and denitrifiers are present simultaneously in the anaerobic compartment. Thus, the availability of the VFA is often the limiting factor when a BNR process is implemented, with one of the most important factors being the selection of the microorganisms present in the culture. The presence of anoxic environments in the BNR processes allows the growth of the fraction of PAO that can utilise nitrates as electron acceptors (DNPAO) [11]. The

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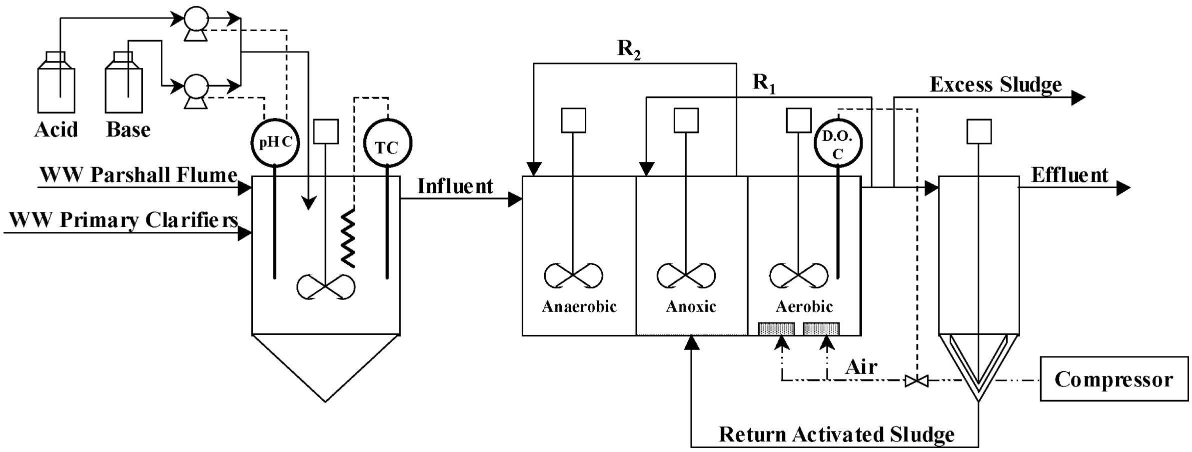

Fig. 1. Schematic flow diagram of the pilot plant.

growth of DNPAO bacteria can be advantageous because the same organic substrate is used for both phosphorus and nitrogen removal. A lack of phosphorus in the influent wastewater stimulates the development of the GAO because phosphorus is not available for polyphosphate accumulation [5].

Modification of the characteristics of the influent wastewater causes a modification in the activated sludge population; both of these changes determine the contaminant concentration in the effluent wastewater. However, due to the large number of processes involved, it is difficult to predict empirically the evolution of the system.

In this context, one of the most powerful tools to predict the COD, P and N removal from wastewaters and the population of the activated sludge is mathematical modeling. However, the complexity of the processes involved and the limited experience in BNR have meant that such models have rarely been used.

The aim of the work described here was to study the influence of long term industrial wastewater discharges on a VIP process optimised for the treatment of urban sewage. The effects of the conditions on the effluent quality and on the activated sludge population were evaluated using modeling and simulation techniques. The modeling and simulations were undertaken using a model for the process that involved GAO [12] integrated into ASM2d [13].

2. Methods

2.1. Pilot plant

The activated sludge for BNR was developed in a VIP stainless-steel pilot-scale plant (Fig. 1) optimised for the treatment of urban sewage [14].

The main feature of the VIP process is that both the return activated sludge and the internal recirculation from the aerobic tank are recycled to the anoxic compartment. In this way, the contents of this anoxic compartment are recycled to the anaerobic compartment. This recycle sequence decreases the possibility of introducing nitrates into the anaerobic zone. In this process, the flow rate of the internal recycles can be optimised to minimise the nitrate concentration entering the anaerobic compartment, a condition that enhances the biological phosphorus removal.

The pilot plant was located at the Ciudad Real WWTP. This pilot plant consisted of an equalisation tank (volume 500 L), a bioreactor (total volume 336 L) divided into three consecutive compartments (anaerobic, anoxic and aerobic) and a settler equipped with a slowly rotating scraper. Variable speed peristaltic pumps were used for internal recycles between compartments, settled sludge recycle to the reactor and also to feed the influent wastewater to the pilot plant.

The solid retention time (SRT) was 8 days in all experiments and the waste sludge was discharged from the aerobic reactor in order to keep the SRT constant. The dissolved oxygen in the aerobic compartment was set to 2.0 g m^{-3}.

The influent flow rate was intentionally kept constant so that the experimental results would reflect only the effect of the wastewater characteristics. The hydraulic operational data and volumes of the pilot plant are summarised in Table 1.

The pilot plant was configured to mimic the hydraulic patterns of the full-scale plant.

Pump flows for influent wastewater, internal recycles, sludge recycle and sludge waste flow were checked before and after each experiment.

2.2. Experiments

The pilot-scale plant was used in all the experiments. During these experiments the pilot plant was continuously run with sewage fed from the Ciudad Real WWTP.

The influent wastewater fed to the pilot plant was prepared by mixing sewage taken from the Parshall flume and from the primary clarifiers of the full-scale plant in a 1:1 volumetric ratio. This mixture was employed because the future lay-out of the process will include a bypass of the primary clarifier. The objective of this bypass is to enhance the nitrogen removal [15].

The experiments were carried out at controlled temperature and pH (the temperature set point was kept at 20 °C and the pH in the range 7.2–7.6). The pH was controlled in order to avoid