Journal of Water Process Engineering 23 (2018) 134–141

Contents lists available at ScienceDirect

Journal of Water Process Engineering

journal homepage: www.elsevier.com/locate/jwpe

Nitrification/denitrification of real municipal wastewater in an intermittently aerated structured bed reactor

Camila Zoe Correa[a,*], Kátia Valéria Marques Cardoso Prates[a], Edson Fontes de Oliveira[a], Deize Dias Lopes[b], Ana Cláudia Barana[c]

[a] Department of Environmental Engineering, Federal Technological University of Paraná, Av. Dos Pioneiros 3131, CEP 86036-370, Londrina, Parana, Brazil
[b] Department of Civil Construction, State University of Londrina, Rodovia Celso Garcia Cid, Km 380 e Campus Universitario, CEP 86057-970, Londrina, Parana, Brazil
[c] Department of Food Engineering, State University of Ponta Grossa, Av. Gal. Carlos Cavalcanti 4748, CEP 84030-900, Ponta Grossa, Parana, Brazil

ARTICLE INFO

Keywords:
Simultaneous denitrification and nitrification (SDN)
Material support
Analysis of variance (ANOVA)

ABSTRACT

The aim of this study was to evaluate the removal of nitrogen and organic matter in real municipal wastewater using a structured bed reactor operated under different intermittent aeration (IA) cycles, as well as to verify if these cycles interfere in the concentration of nitrifying and denitrifying bacteria. Three phases of aeration (O) and non-aeration (A) were studied in this research: phase 1 (4 h O/2 h A); 2 (2 h O/1 h A) and 3 (2 h O/2 h A). Even with the variation in the operating conditions and the different loads of organic matter and nitrogen applied, the system remained stable in relation to the removal of organic matter (above 80%). The best condition for removal of NH_4-N and TKN was obtained in phase 2, with removal percentages of 86 ± 15 and 80 ± 15% respectively. The results of phase 2 for the removal of NH_4-N, denitrification (74 ± 15%) and removal of TN (68 ± 9%), indicated that at this stage the simultaneous denitrification and nitrification process (SDN) occurred. At this stage, the mean concentration of AOB was 3.10^{10} MPN $gVSS^{-1}$, NOB 1.10^{7} MPN $gVSS^{-1}$ and denitrifying 9.10^{11} MPN $gVSS^{-1}$. The analysis of variance (factorial ANOVA) applied to the different groups of microorganisms analyzed indicated that there was a significant difference among the abundance of these organisms in the different IA cycles, but the difference among these groups depends on which places and phases are being considered.

1. Introduction

In Brazil, out of the 5570 existing municipalities, 3069 (55%) have sewage collection systems and only 29% of them treat the wastewater collected [1]. In the country, from the entire organic load generated by the population daily, only 39% is removed by the existing sewage treatment infrastructure. As a result, in terms of remaining organic load, about 5.5 thousand tons BOD/day reach the recipient bodies [2]. The sewage treatment systems used mainly aim to remove solids and organic matter, however these are not the only constituents that can cause problems to the environment.

The macronutrients in domestic sewage, such as nitrogen, when not removed adequately, may cause damage to the environment such as eutrophication, reducing dissolved oxygen concentration in the environment, and leading to fish mortality and human health related problems [3].

Biological treatment is the most commonly used technique to remove organic matter and nitrogen, due to its low cost and high efficiency. The biological removal of organic matter occurs through the action of heterotrophic microorganisms, while the removal of nitrogen is carried out by a series of oxidation and reduction processes. The oxidation process of N-ammonia (NH_4-N) to nitrite (NO_2^--N) and later to nitrate (NO_3^--N) occurs conventionally through the action of aerobic nitrifying bacteria (ammonia oxidizing bacteria – AOB and nitrite oxidizing bacteria – NOB). In the denitrification process, facultative heterotrophic bacteria reduce NO_2^--N and NO_3^--N to N_2, in the absence of molecular oxygen.

Nitrifying bacteria species are highly sensitive to environmental conditions such as pH, alkalinity, temperature, dissolved oxygen (DO), and NH_4-N, NO_2^--N, and NO_3^--N concentrations. Furthermore, they have a low growth rate and are easily washed out of treatment systems [4,5]. Thus, it is necessary to use techniques that will keep them in the system and enable their development, such as long hydraulic retention time (HRT), solids retention time (SRT), and immobilized biomass.

The structured bed reactor is a new alternative for biologically treating wastewater. In this type of reactor, a high concentration of

* Corresponding author.
E-mail address: camila.zoe@anhanguera.com (C.Z. Correa).

https://doi.org/10.1016/j.jwpe.2018.03.013
Received 26 September 2017; Received in revised form 13 March 2018; Accepted 20 March 2018
2214-7144/

biomass, adhered and suspended, is maintained inside, resulting in long solids retention time. Studies on this reactor with intermittent aeration cycles (IA), on a bench scale, have obtained good results in the removal of nitrogen and organic matter (above 70%) [6–8]. However, there are no studies of this configuration of the reactor with intermittent aeration (IA) applied to the treatment of real municipal wastewater. IA may lead to a simultaneous nitrification and denitrification (SND) process, bringing some benefits to treatment plants, such as energy savings and the non-use of external sources of alkalinity for the nitrification process, which is important in the treatment of effluents with high concentrations of nitrogen.

Considering the above, the aim of the study was to evaluate nitrogen and organic matter removal from real municipal sewage with high concentrations of nitrogen, using a self-inoculated structured bed reactor, operating at different intermittent aeration cycles. The influence of aeration cycles on the concentration of nitrifying and denitrifying bacteria, adhered and suspended, was also investigated.

2. Material and methods

2.1. Experimental installation

The bench scale experimental installation consisted of a continuous flow reactor, built in acrylic, with an external diameter of 22 cm, internal diameter of 16 cm, and height of 82 cm, total volume of 12 L. As support material, cylindrical polyurethane foam structures about 3 cm in diameter and 65 cm in height were used, totalling 13 structures inside the reactor, generating a bed with porosity of 28%. For vertical fixation of the cylindrical structures in the reactor, PVC rods were used, fitted at the ends, as proposed by Barana [7] and Moura [8] (Fig. 1).

The reactor was fed by a positive displacement pump (ProMinent GAIA model–maximum flow: 1.2 L h^{-1}). For aeration, three air pumps (Mark: BIG ALPHA A230) were used, connected to porous stones that provided an airflow rate of approximately 9.5 L min^{-1}. During the system operation, the nitrified effluent was recirculated three times in the entry flow (Q_{re} = 3Q). Recirculation was done through a pump of the same brand and model as that used for feeding.

The system was operated for 194 days, at room temperature (25 ± 1 °C). This period was divided into two times: start-up (33 days) – HRT of 58 h, and operation phase (161 days) – HRT of 16 h. The operation phase was divided into 3 phases, with different IA cycles (turned-on aeration – O/turned-off aeration – A): phase 1 (4 h O/2 h A – 66 days), phase 2 (2 h O/1 h A – 45 days), and phase 3 (2 h O/2 h A – 50 days). The duration of these phases was obtained in function of the time necessary to observe the lowest results variability, that is, until a "steady state" is verified.

2.2. Real municipal wastewater

The real municipal wastewater came from the Sewage Treatment Station (STS) of the Paraná Sanitation Company – STS North/Sanepar, located in the city of Londrina – PR, and was collected weekly after the preliminary treatment (screening and grit removal). At the time of use, a 20 L reservoir was filled at ambient temperature, where the sanitary sewer was pumped in and fed to the reactor. Table 1 presents the characterization of the municipal wastewater used.

2.3. Reactor self-inoculation

In order to start the operation of the system effectively, an inoculum was obtained from the continuous aeration of municipal wastewater in a sequencing batch reactor (SBR), operated with 24 h HRT, until the nitrifying organism activity was verified (30 days). After this period, the sludge formed in the SBR was placed in contact with the cylindrical structures of polyurethane used as support material in the structured bed reactor for a period of 24 h.

After this time, the cylindrical structures were installed in the reactor, which was operated under continuous aeration and flow with 58 h of HRT, to favor the adaptation and fixation of the biomass, initiating the autoinoculation phase of the reactor. After 33 days, removal of 100% of NH_4-N in the effluent was verified, and the study of the system was started effectively, with the binding of IA and HRT alteration.

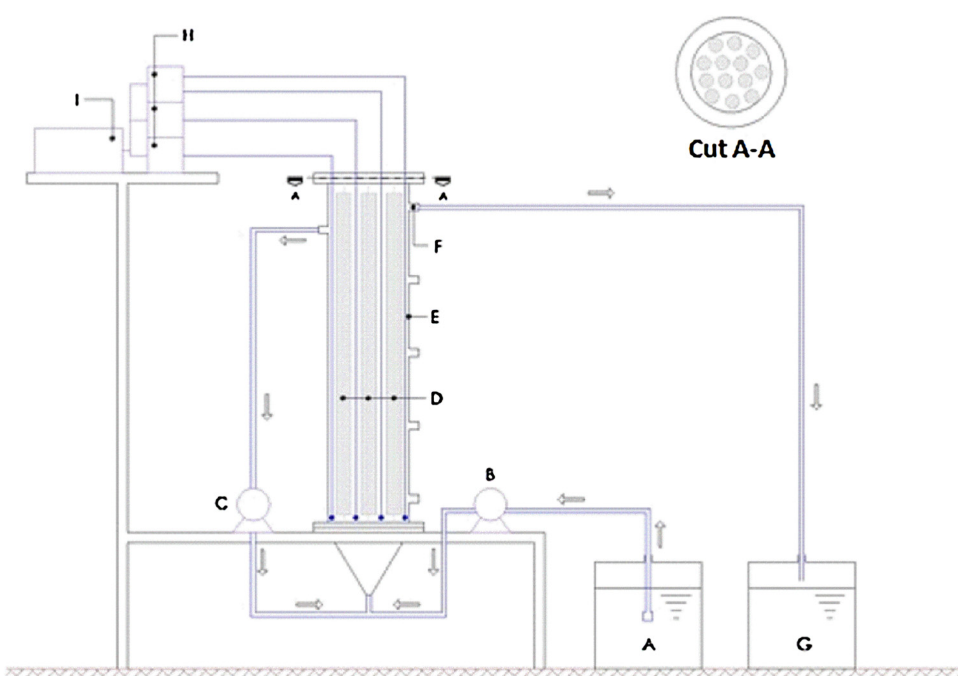

Fig. 1. Schematic representation of the treatment system used: A – Attachable sewage sanitary reservoir; B – Feed pump; C – Recirculation pump; D – Material support; E – Structured Bed Reactor – RLE; F – Outflow of sewage effluent; G – Sewage effluent reservoir; H – Aeration pumps; I – Analog timer.