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Treatability of landfill leachate combined with sanitary sewage in an activated sludge system

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ABSTRACT

Landfill leachate is one of the major problems generated from waste; it has high concentrations of biodegradable and refractory organic and inorganic matter such as ammonia and heavy metals. The combined treatment of leachate with sewage has been used in various sewage treatment plants in the world. However, there are still many questions and uncertainties about the process, especially the effects of adding leachate to the treatment system. In this context, the objective of this work is to evaluate the efficiency of combined leachate/sewage treatment in activated sludge under different conditions. Treatability experiments were carried out using a bench scale (SBR) process using the volumetric proportions of 0 (control), 2 and 5% leachate under different experimental conditions. Experiment 2 (leachate pre-treated by alkalinization and air stripping) was technically more feasible, achieving removal efficiencies of BOD, COD and DOC above 97%, 82%, 60%, respectively, and the highest diversity indices of the bacterial and eukaryotic communities and flake structure stability were observed up to a volumetric ratio of 2% of pre-treated leachate. The DGGE technique used showed that populations of eukaryotes were apparently the most affected with increasing proportions of 2%–5% of the mixture, mainly for experiments 3 (B3R2) and 4 (B4R4), where the lowest diversity indices of these populations were found.

1. Introduction

Landfills are still used in Brazil because they are technically and economically feasible, while in developed countries there is a tendency to reduce or extinguish this form of final disposal of solid waste. Furthermore, the disposal of municipal solid waste in landfills has increased over the last years in the country due to the current Brazilian legislation (Law 12,305/2010 – National Policy on Solid Waste) [1], which prohibits the maintenance of dumps in the country and determined a deadline for replacing them with sanitary landfills. According to the "Brazilian Association of Public Cleaning and Special Wastes" [2], of the 78.6 million tons of solid waste generated in 2014, 29.6 million tons were disposed of in dumps and controlled landfills, which are considered inadequate and pose risks to human health and the environment.

In developed countries with limited land availability, the landfill alternative is not the preferred method [3,4] and the incineration process is the most commonly used for urban solid waste treatment [5]. Since the regulations which restrict the disposal of organic materials in landfills were established, member countries of the European community are seeking for effective ways to treat the organic matter of MSW [6]. Some of these approaches are anaerobic digestion of the organic fraction of MSW for the production of bio-methane [7], nutrients [8] and biohydrogen [9].

A negative aspect related to landfills concerns the gases produced which are not captured by the system and eliminated in the atmosphere. The leachate generated in landfills is a potential pollution source, mainly due to the high concentrations of ammoniacal nitrogen, biodegradable organic matter, refractory and heavy metals. When it is not collected, transported and treated properly, it can cause environmental impacts such as the pollution of water resources and public health problems [10].

The ideal landfill leachate treatment to prevent negative environmental impacts is still a challenge. One alternative is the biological treatment of leachate mixed with domestic sewage, resulting in an effluent that meets the legal requirements. The mixture of leachate with sanitary sewage has shown good results, using the correct mixture percentages [11–14].

The combined treatment of leachate with domestic sewage has been used in several countries as a way to reduce the costs of implementing treatment units in landfills and operational costs over a long period of time. In Brazil, the use of this combined treatment has become more and more widespread. The Bandeirantes, São João, Vila Albertina and Santo Amaro landfills, in São Paulo (SP), Tupã landfill (SP), Baleia

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landfill in São Sebastião (SP), Meridiano (SP) and Extrema, Porto Alegre (RS), Salvaterra, in Juiz de Fora (MG), CTR-BR040, in Belo Horizonte (MG), and Morro do Céu in Niterói (RJ) are Brazilian examples of combined leachate and domestic sewage treatments [15–17,10]. Also several configurations of reactors have been used in other countries to promote the combined treatment of leachate with domestic sewage [18–20].

The efficiency of the conventional biological treatment of leachate in the activated sludge system is affected by the high concentrations of free ammonia, which is potentially toxic to aerobic microorganisms at the high concentrations found in the leachate (concentrations higher than 800 mg L^{-1}) [18]. The pre-treatments indicated for ammonia removal include precipitation, coagulation-flocculation, adsorption, chemical oxidation and air stripping [21–25].

In this context, the objective of this research was to evaluate the treatability of domestic sewage mixtures with raw and pre-treated leachate and anaerobic effluent mixtures with raw and pre-treated leachate in bench-scale activated sludge system and characterize the microbial community by demonstrating the performance of the system submitted to the different operating conditions.

2. Materials and methods

2.1. Leachate and domestic sewage

The leachate was collected at the end of the sanitary landfill drainage system in São Carlos (SP), Brazil, coordinates 21°56′56″S and 47°55′14″W in the Tietê Jacaré Hydrographic Basin. Such landfill served the city for about 20 years and it is considered a stabilized system [26]

The sanitary sewage was collected from the sewage system of a residential region and after passing through a hose reel it was accumulated in a suction well, after which it was repressed to feed the reactors used in that work process.

The leachate was subjected to pre-treatment by chemical precipitation with the addition of lime to pH 11. Then, the ammonia was removed in an air stripping tower (2.25 m height and 15 cm diameter), filled with raschig rings made of polyethylene with corrugated walls of 1.5 cm internal diameter and 5 cm length. Two 6 L washing flasks were used to recover the ammonia, with 4 L of 0.4 mol L^{-1} sulfuric acid, with an average efficiency of 80% [25].

The ammonia concentration in the effluent was 20 mg L^{-1} (maximum value established in Brazil through Resolution 430/2011 of the National Environmental Council, CONAMA) [1], although this resolution does not require that this limit be met in plants receiving leachate of landfill.

2.2. Experimental equipment and design

The aeration chamber used in the bench-scale experiments consisted in four chambers separately operated with uninterrupted aeration: R1, R2, R3 and R4, with individual volume of 10 L containing internal decanters for the partial separation of sedimented solids. In addition, each chamber was equipped with an external 8-l decanter (Fig. 1).

2.3. Inoculation and adaptation of biomass

Activated sludge reactors were inoculated with aerobic sludge from the batch activated sludge treatment system of a paper and cellulose industry. The collected sludge presented good sedimentability and low concentration of filamentous microorganisms. The inoculum volume (25% of the reactor volume) was adopted so that after inoculation and filling the reactors with sewage, each chamber could operate with suspended solids concentration of approximately 2000 mg L^{-1}. The adaptation of the inoculum was performed in a 60-l capacity reactor with the mixture of 30 L of sewage, 10 L of the aerobic sludge and

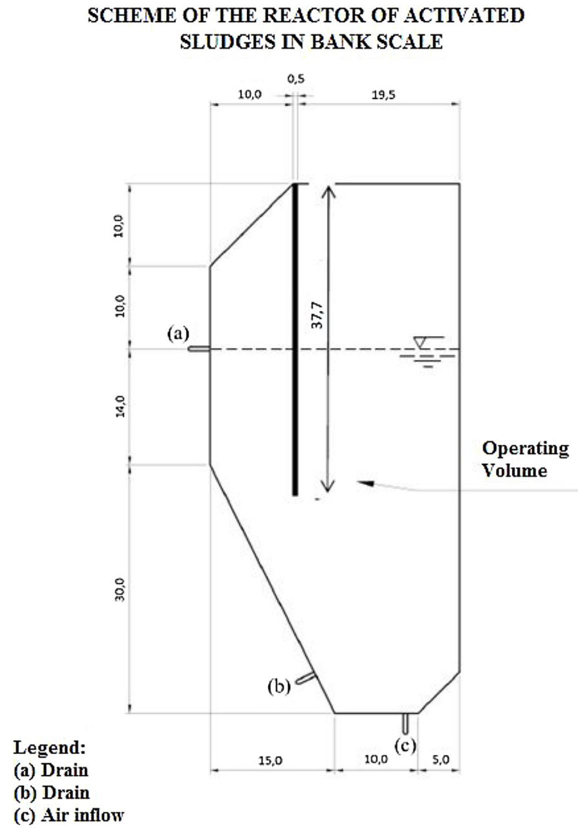

Fig. 1. Schematic section of activated sludge reactor on bench scale. (mesures in centimeter). Adapted by Turetta [14].

aerated for 22 h. A volume of 20 L of this aerated mixture was subjected to 2 h of sedimentation and after the supernatant was discarded and the sedimented sludge was returned to the reactor and the volume was filled with sewage. The procedure was repeated for seven days by microscopic monitoring of the microbiota degradation of organic matter. During adaptation, the pH was maintained at around 7.0 and the dissolved oxygen above 2.0 mg L^{-1} [27].

2.4. Experimental procedures and analytical methods

In this work, four tests were developed: the mixture of domestic sewage with raw leachate (E1); the mixture of domestic sewage with pre-treated leachate (E2); the mixture of sewage effluent from anaerobic reactor with pre-treated leachate (E3); the mixture of anaerobic reactor effluent with raw leachate (E4). Table 1 shows the physical-chemical characterization of domestic sewage, effluent from the anaerobic reactor, raw and pre-treated leachate followed the methodologies described by Eaton et al. [28]. The treatability of the mixtures was evaluated at different proportions of leachate (0%, 2% and 5%).

The four reactors were operated using a 24 h cycle. After 23 h of aeration of the mixture, 7 L of the contents of each chamber was separated and after 1 h of sedimentation, 5L of supernatant was discarded. The sedimented sludge was returned to the reactor and the volume was filled with the leachate/sewage mixture. The mixture was prepared daily for each reactor. Aeration in the chambers was not interrupted during the sedimentation period. This procedure was performed until the end of the experiment. Each experiment lasted 20 days/operation and a 2-day hydraulic retention time (HRT) was maintained. After these batch assays, the pilot scale of a conventional activated sludge reactor with continuous regime was operated for 64 days according to the best COD and nitrogen removal results obtained in the batch assays (E2). The pilot scale activated sludge system consisted of a stainless tank, an aeration tank (100L), decanter and