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Evaluation of a upflow anaerobic sludge blanket reactor with partial recirculation of effluent used to treat wastewaters from pulp and paper plants

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Abstract

The main purpose of this study was to evaluate the performance of a UASB reactor treating diluted black liquor from a Kraft pulp mill, which simulates an unbleached Kraft plant wastewater, under different operational conditions, including partial recycling of the effluent. The reactor's performance was evaluated from the standpoint of COD, pH, volatile acid concentration, alkalinity, concentration of methane in the biogas, and microbiological examinations of the sludge. Without recirculation the reduction of the HRT from 36 to 30 h did not significantly affect the average COD removal efficiency. The parameter displaying the greatest variation was the average concentration of effluent volatile acids, which increased by 16%. With recirculation the reduction of the HRT from 30 to 24 h increased the average COD removal efficiency from 75% to 78%. In this case, the average effluent alkalinity also showed an increase. The use of partial recirculation of the effluent did not improve significantly the COD removal under the operational conditions tested in this work, but it was possible to operate the reactor with lower hydraulic retention time without disintegration of the granules.

Keywords: Anaerobic process; Black liquor; UASB reactor; Pulp and paper wastewaters; Wastewater treatment

1. Introduction

The pulp and paper industry is responsible for large discharges of highly polluted effluents, whose main characteristics are their high toxicity and low biodegradability of their tannins, lignins, resins and chlorophenolic compounds. The composition of these effluents, which has a great influence on its treatability, may vary considerably, depending on the raw material and manufacturing process utilized (Sierra-Alvarez, 1990; Kortekaas et al., 1998; Vidal et al., 2001; Thompson et al., 2001). It should also be mentioned that the liquors from alkaline pulping (Kortekaas et al., 1998), wood resins (McCarthy et al., 1990; Sierra-Alvarez, 1990) and tannins (Sierra-Alvarez, 1990) are potentially toxic to methanogenic *Archaea*. Moreover, the degradation of lignin by the anaerobic consortium is limited to the low molecular weight fraction (Sierra-Alvarez, 1990; Kortekaas et al., 1998; Vidal et al., 2001). Until now aerobic treatment systems are the most widely used method to treat effluents from pulp plants. However due to lower operational costs and the potential to degrade some recalcitrant compounds, the anaerobic treatment process is an alternative that must be considered.

The anaerobic process has been successfully applied in the treatment of nontoxic and easily biodegradable wastewaters from pulp and paper plants, such as the effluents from mechanical pulping, from paper recycling and from evaporator condensates. However, the high toxicity of the effluents from chemical, semi-chemical and chemo-thermo-mechanical pulping have restricted the application of the

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anaerobic process for the treatment of these effluents (Kortekaas et al., 1998).

The advances in the application of UASB (Upflow Anaerobic Sludge Blanket) reactors in the treatment of industrial wastewaters and domestic sewage, allied to considerable research on the system have consolidated the technology (Lettinga et al., 1991). Nonetheless, the scientific and technological studies, developed over the years, have also played a crucial role in identifying the negative points of this system and the adverse conditions for its practical application. As a result of this research it is known that the use of UASB reactors in the treatment of complex effluents often requires long hydraulic retention times (Speece, 1996). In UASB reactors the upward velocity is very low, hindering the mass transfer processes. Campos and Anderson (1992) found that the upward velocity exerts a considerable effect on the development of sludge in UASB reactors, acting as a selector in the development of the biomass. An increase in the flow velocity, that may improve the reactor performance, can be achieved by partial recirculation of the effluent.

Buzzini and Pires (2002) evaluated the performance of a bench scale UASB reactor treating diluted black liquor from Kraft pulp plant. The average COD (chemical oxygen demand) removal efficiency during 635 days of continuous operation was 80%, however the hydraulic retention time was high (approximately 40 h). According to the authors the UASB reactor demonstrated capability to treat this kind of wastewater, however after approximately 60 days from initiation of operation the granules started to disintegrate and the sludge became flocculent.

The formation of a flocculent sludge when the reactor is fed with dilute influent and/or with relatively low upflow velocities, may be due to a type of natural selection, as this type of sludge has lower mass transfer resistance compared to granular sludge (Nicolella et al., 2000). Therefore, the substrate is more accessible to the biomass in the flocculent sludge. However, the biogranules settle more effectively, due to larger sizes than the suspended sludge in the reactor, and thus have less tendency of being washed out. Moreover, the microbial distribution seems to suggest that granules should be less vulnerable than the suspended sludge to the chemical toxicity of pollutants in wastewater (Fang, 2000).

The black liquor is the main component of the liquid effluent from the production of unbleached Kraft pulp. According to Mansilla et al. (1993), black liquor can closely represent the constituent of the effluent of a Kraft pulping plant. Black liquor is a by-product generated in the decomposition of the constituents of wood during the chemical pulping process. In a later stage, this liquor is concentrated by evaporation and then burned in order to recover energy and inorganic compounds for reuse in the industrial process. It must be kept in mind, however, that part of the liquor is released in the wastewater as the pulp is washed.

The main objective of the work described here was to assess the performance of an UASB reactor treating diluted black liquor from a Kraft pulp mill, which simulates an unbleached Kraft plant wastewater, under different operational conditions, including partial recycling of the effluent.

2. Methods

2.1. Reactor design

An UASB-type reactor with a total volume of 15.0 L was used. This reactor was made of plexiglass and the gas–solid–liquid separator of ANSI 316 stainless steel. The development of the sludge blanket occurs in the reaction zone, which is 45 cm high with a circular section of 15 cm in diameter. The gas–solid–liquid separator is located 60 cm from the reactor's entrance (Fig. 1).

The reactor, kept in a chamber acclimatized at a temperature of 30 ± 3 °C to prevent any possible interference caused by variations in temperature, was fed using a dosing pump (Prominent, model Gamma G/4b, São Bernardo do Campo, SP, Brazil) with a maximum outflow of 2.3 L h^{-1}. A similar pump was used for recirculating the effluent.

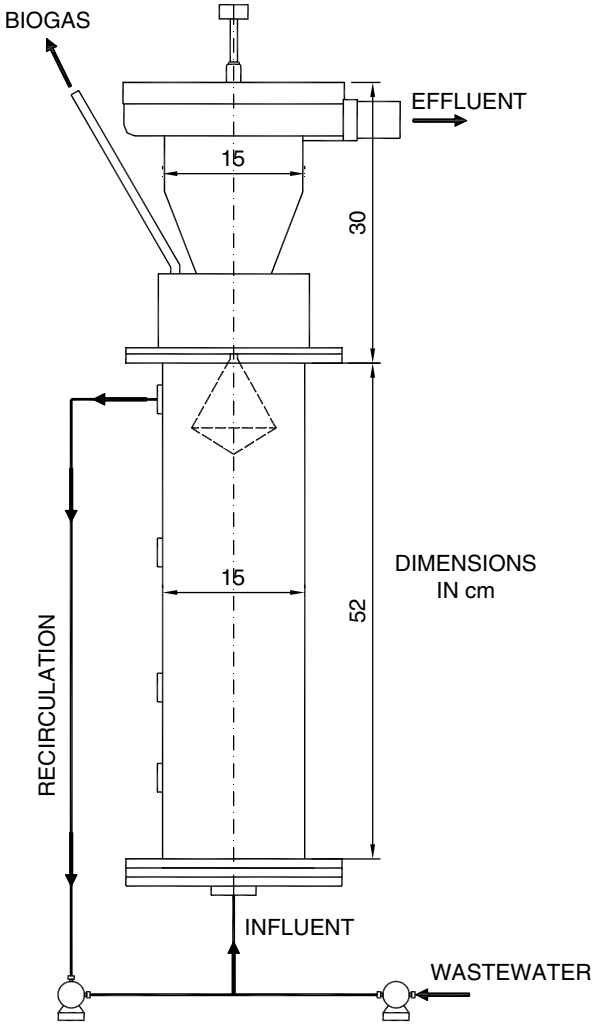

Fig. 1. Diagram of the UASB reactor.