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Biological nitrogen and phenol removal from saline industrial wastewater by submerged fixed-film reactor

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Abstract

In this study a biological nitrogen removal process using a submerged fixed-film reactor was applied to treat industrial wastewater with phenol (1 g/l), a high nitrogen concentration (0.4 g N/l) and high salinity (30 g/l). The process consisted of a pre-denitrification system with a down-flow-up-flow biofilter (two columns, each with an effective volume of 21 l) packed with clayey schists from recycled construction material. The efficiency of the system for reducing COD, phenol concentration and total nitrogen was tested under different running conditions such as influent flow (10, 12 and 15 l/d), air loading (6.8 and 13.6 m^3/m^2 h) and effluent recirculation (300%, 400%, and 600%). The system demonstrated a high capacity for reducing COD concentration (95.75 ± 0.72%), independently of running conditions. The aerobic column eliminated most of the phenol in the influent. Nitrogen removal took place mainly in the anoxic column, and was conditioned by the air loading in the aerated column, owing to the dependence of nitrification on the supply of oxygen. However, this process was not able to achieve a nitrogen oxidation superior to 63%, in spite of a sufficient supply of oxygen and the diluting effect of high recirculation (600%) on the phenol concentration in the influent. In spite of the limitations observed in the process of nitrification, results for the removal of total nitrogen were as high as 83%, owing to a combination of different processes for nitrogen removal.

Keywords: Nitrogen removal; Phenol; Industrial wastewater treatment; Pre-denitrification; Submerged fixed-film reactor

1. Introduction

Discharge of industrial wastewater is the cause of significant deterioration of the environment largely because of the presence of nutrients such as nitrogen. These types of pollutants are responsible for phenomena such as the eutrophication of estuaries and coastal areas [1]. Accordingly, priority is now being given to eliminating nutrients from wastewater before it is discharged offshore.

The biological process of nitrification–denitrifaction is generally used to eliminate nitrogen from wastewater, particularly in the case of urban wastewater [2]. Nevertheless, applying this process to the treatment of industrial wastewater is complicated because of the characteristics of the effluent, which make it extremely difficult to be treated biologically. For this reason, nitrogen compounds have traditionally been eliminated from industrial effluents by means of costly physical–chemical processes [3,4].

Certain chemical-pharmaceutical industries generate wastewater containing an extremely high level of ammonium and phenol, something, which virtually rules out any kind of biological treatment. One possibility is to reduce the concentrations of pollutants by diluting them to levels which, though still high, are low enough to permit the application of biological processes [5,6]. In industries located in coastal areas, sea water can be used as a diluting agent. However, this adds still another factor to be considered, namely the corresponding increase in salinity. Nevertheless, authors such as Glass and Silverstein [7] have successfully used biological technologies for the treatment of effluents with an ionic force of 3.0.

Most biological treatments of nitrogen involve a combination of two separate reactors under aerobic conditions (nitrification) and anoxic conditions (denitrification). Nitrification is the

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autotrophic oxidation of the ammonia, first to nitrite and then to nitrate. Accordingly, denitrification consists of the microbiological eduction of nitrate and nitrite to a gaseous nitrogen compound. The integration of this biological process is possible in two separate configurations: pre-denitrification and post-denitrification. Combination of an anoxic process followed by an aerobic process without the addition of an external carbon source and involving the internal recirculation of the treated effluent (pre-denitrification) is more frequently applied to wastewater with a high organic content [2].

In industrial wastewater treatment, nitrogen removal can be combined with the elimination of toxic substances such as phenol, which in spite of its anti-microbial effect, can be used by various micro-organisms as a carbon source for carrying out heterotrophic denitrification [8]. This combination makes the application of biological processes to the treatment of industrial wastewater doubly interesting.

High salt concentrations have negative effects on organic matter, as well as nitrogen and phosphorous removal [9]. However, several halo-tolerant nitrifying and denitrifying bacteria have been isolated and identified in hypersaline waters [10,11]. Glass and Silverstein [7] provide a good review of previous work in this area, and report on both successful and unsuccessful attempts to acclimate activated sludge for treatment of high-nitrate and high-saline wastewater.

In recent years there have been considerable advances in submerged fixed-film reactor technology for the removal of nutrients, and there are currently different configurations, which may be adapted to the effluents treated [12]. Water treatment by submerged fixed-film filter technology requires the formation of a biofilm around an inert substance. In urban wastewater it is possible to form a biofilm from the influent to be treated, owing to the presence of a high microbial loading [15]. However, with industrial wastewater containing extreme concentrations of pollutants, it is necessary to prepare the biofilm previously, and on occasion to allow a period of time for acclimation of the microbial mass [7]. This is a complicating factor in the biological treatment of industrial wastewater.

This article discusses data collected during the final experimental phase of a study on the nitrogen removal capacity of a lab-scale submerged fixed-film reactor for treating industrial effluent with high phenol concentration and high salinity. Operating with down-flow for denitrification and up-flow for nitrification (pre-denitrification configuration), the submerged fixed-film reactor was packed with clayey schists from recycled construction material. The aim of the experiment was to study the effects of influent flow, air loading and effluent recirculation on the removal of nitrogen, COD and phenol from effluent with high salinity.

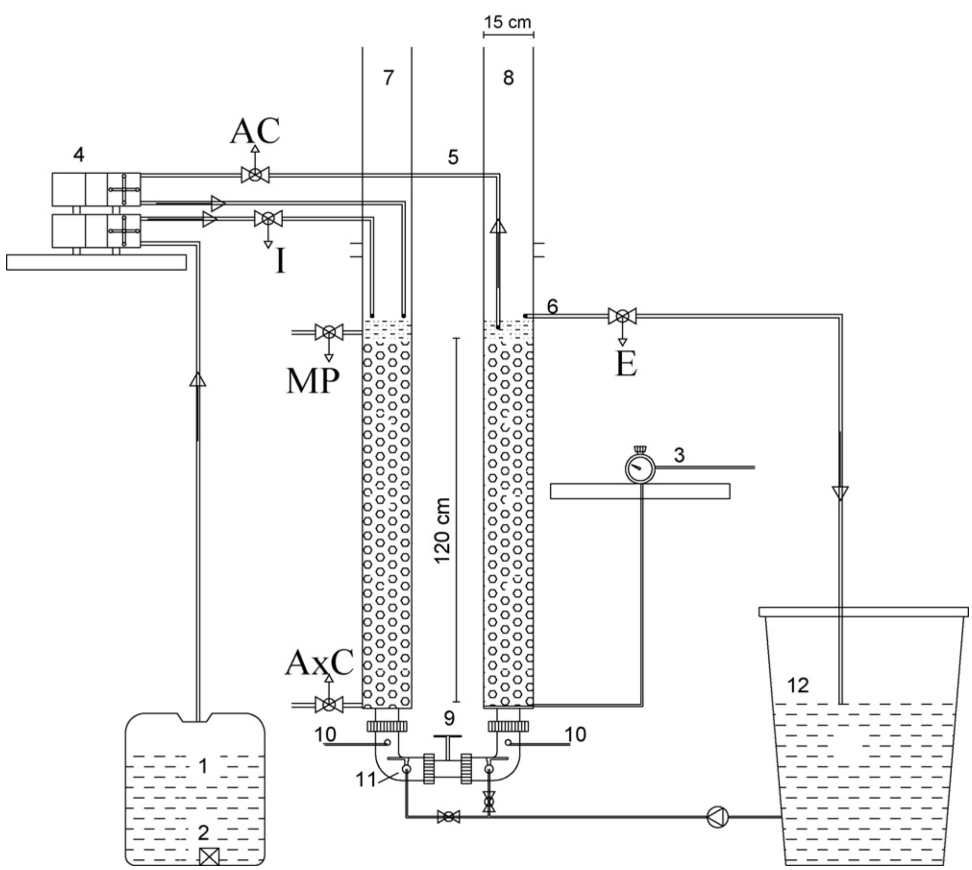

Fig. 1. Lab scale plant process: (1) influent; (2) agitator; (3) air process rotameter; (4) peristaltic pump; (5) recirculation; (6) effluent; (7) anoxic column; (8) aerobic column, (9) valve; (10) inlet air cleaning; (11) inlet water cleaning; (12) outlet water (cleaning water). (I) influent; (MP) influent and effluent recirculation mixed place; (A × C) anoxic column outlet water; (AC) aerobic column outlet water; (E) effluent.