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Experimental and modeling investigations of wastewater filtration

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Abstract

In an effort to make wastewater recycling risk-free, this research investigated the feasibility of using a waste material as filter for the removal of humic substances (HS), and ultimately the toxic hydrophobic organic compounds (HOC) attached to them. Based on the results of earlier studies, laboratory experiments were conducted in a large-scale set up to investigate with synthetic and real (municipal) wastewater, the effects of the flow rate, column diameter, and column height on the efficiency of the filtration process. Furthermore, with the experimental data, a mathematical model was calibrated and used to predict the performance of the filtration process under various conditions.

The results of the investigation with the synthetic samples showed that all concentration-time profiles had a reversed ‘S’ shape, and at any given flow rate, the efficiency of the filtration increased when the height and/or diameter of the PPL column increased. However, it decreased when the flow rate increased. Under similar conditions, the filtration efficiency with municipal wastewater samples was much higher. The mathematical model predicted with more or less success the experimental data. Overall, this research confirmed that PPL can be used to remove HS. It also suggested that PPL may be able to remove HOC attached to HS. Nevertheless, further investigations are necessary to eliminate the release of background organics by PPL, and improve the model by taking into account the dual adsorption–filtration capability of its granules.

Keywords: Filtration; Humic; Hydrophobic organic compounds; Polypropylene; Surfactant; Wastewater

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1. Introduction

Hydrophobic organic compounds (HOC), because of their toxicities to human and other living organisms [1,2], must be removed from wastewater intended for recycling. Previous researches have reported that in the aqueous phase, HOC tend to bind to dissolved organic matters (DOM) such as humic substances (HS), or remain free in solution depending on the prevailing physicochemical conditions [3,4]. In a research carried out to extract contaminants, Muhandiki [5] reported that PPL, a highly hydrophobic material made of recycled waste plastic can remove HOC not bound to HS, however, PPL cannot remove HS and the HOC attached to them. Furthermore, a previous batch and small-scale column investigation by Adou et al. [6] showed that the addition of dedocyltrimethylammoniumbromide (DDTMAB), a cationic surfactant induced a chemical reaction between HS and DDTMAB that led to the formation of complex compounds. The complexes formed, either solute or precipitate, were subsequently removed by filtration through PPL. The removal of the complexes from the aqueous phase then ensured the elimination of the HS.

To confirm the removal capability of PPL, this research was undertaken. The main objective was to investigate in a large-scale column the effects of different physicochemical parameters on the removal of the complex compounds. In addition, a comparative study of experimental data and the predictions of a mathematical model was carried out.

2. Materials and methods

2.1. Experiments with the large-scale column

The effects of the diameter and height of the PPL column and the flow rate were evaluated with the large-scale column described in Fig. 1. Different diameters, heights, and flow rates were tested. The column diameter was successively set at 40 and 80 cm, whereas its height was 20, 25, or 30 mm. The flow rate was set at 0.5, 1.5, and 3.5 L/h, which corresponded to different filtration rates depending on the diameter of the column. The diameter of the PPL granules ranged between 2.8 and 3.35 mm. The porosity of the PPL was 18%, and its bulk density 0.193 g/mL.

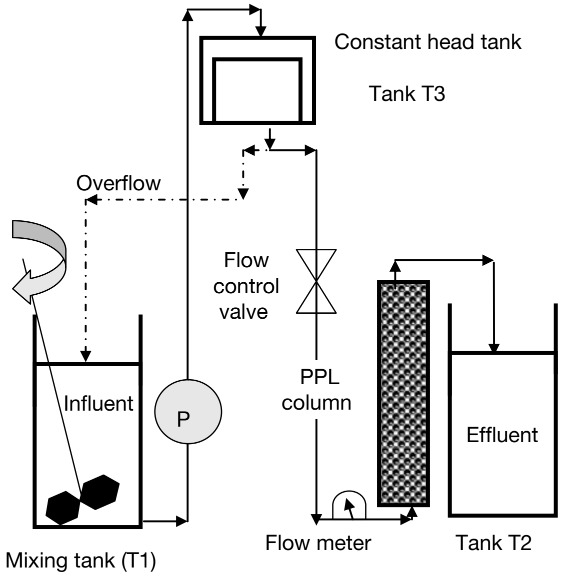

Fig. 1. Layout of the large-scale experimental set up.

The experiments were conducted with both synthetic water and wastewater samples. To make the synthetic wastewater, first 40 L of tap water was mixed with a stock solution of humic acid (HA), selected to represent the HS, to yield 10 mg/L TOC HA solution. Then, 5 mg/L of DDTMAB were added to the solution. After that, the solution was mixed at 1300 rpm with a stirrer for 10 min. As for the real wastewater samples, they were collected from a municipal wastewater treatment plant and were adjusted to a TOC of 10 mg/L before use. All experiments were conducted at 25°C, in a dark room to prevent the degradation of the HA solution. Influent and effluent samples were collected regularly.

Before analysis, the samples were filtrated using a 0.45 μm pore size filter to separate the precipitates formed during the reaction