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Application of ultrafiltration membranes for removal of humic acid from drinking water

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Abstract

Humic acids are primarily a result of the microbiological degradation of surrounding vegetation and animal decay and enter surface waters through rain water run-off from the surrounding land. This often gives rise to large seasonal variations, high concentrations in the wet season and lower concentrations in the dry season. Alone humic acid is just a colour problem but when present in conventional treatment processes like chlorination, carcinogenic by-products like trihalomethane and haloacetic acid are formed. This, in addition to the demand for clean potable drinking water, has sparked extensive research into alternative processes for the production of drinking water from various natural/industrial sources. One of the major areas of focus in these studies is the use of membranes in microfiltration, ultrafiltration and nanofiltration. In this report the humic acid removal efficiency of ultrafiltration membranes with 3 kDa, 5 kDa and 10 kDa MWCO is examined. The membranes were made of regenerated cellulose and were in the form of cassette providing a 0.1 m^2 surface area. At first distilled and deionised water, known as milliQ water, was used as the background feed solution to which humic acid powder was added. It was found that all three membranes removed humic acid with an efficiency of approx. 90% and were capable of reducing initial concentrations of 15mg/L to below the New Zealand regulatory limit of 1.17 mg/L. The permeate flux at a transmembrane pressure of 2.1 bar was approx. 20 l/m^2/h (LMH) and 40 LMH, respectively through the membranes with MWCO 3 kDa and 5 kDa. These membranes experienced significant surface fouling resulting in retentate flow rates as low as 11 litres per hour after just four runs compared to the recommended 60–90 l/h. Cleaning with 0.1 M NaOH slightly improved the retentate flow rate, but well below those obtained with fresh membranes. The 10 kDa membrane provided high retentate flow rates which evidently minimised fouling by providing a good

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sweeping action across the membrane surface while maintaining humic acid removal below the regulatory 1.17 mg/L level. The permeate flux through this membrane was initially high (140–180 LMH) and reduced to approx. 100 LMH after 10–12 min of operation. Increasing the initial humic acid feed concentration from 10 mg/L to 50 mg/L did not significantly decrease humic acid removal efficiency although the retentate flow rate was lower at higher concentrations. Finally the tap water was tested as the background solution and treated for the removal of humic acid. The presence of ions and other impurities in the tap water had little effect on humic acid removal. However, the permeate flux through 10 kDa membrane decreased from 100 LMH for milliQ water to 60 LMH for tap water after 20 min of operation.

Keywords: Humic acid; Ultrafiltration; Membrane; Flux; Removal

1. Introduction

Increasing regulations and the need for a reliable potable drinking water supply has raised interest in the use of membranes for microfiltration (MF), utrafiltration (UF) and nanofiltration (NF) in the drinking water treatment process. These membranes use pressure as the driving force to separate out contaminants from water supplies. They are being considered as a replacement for many of the unit processes which are currently implemented, such as sand filtration, carbon adsorption or ion exchange.

One particular group of contaminants that is present in water supplies and which has brought about concern in the water industry are humic substances (HS). There are three substances which make up HS and they are; humin which is completely insoluble, humic acid (HA) which is insoluble at a pH of 1 and fulvic acid (FA) which is soluble at any pH. Humic acids are suspected to be a result of condensation polymerisation reactions, amino acid sugar interactions, lignin biodegradation, animal and plant decays [1]. However there have also been humic acid concentrations in surface waters that are heavily affected by changes in the weather. High temperatures will induce the decomposition of microorganisms and organic material while heavy rainfall will increase water run-off into rivers and lakes, giving rise to significant seasonal variation in non-temperate environments.

Humic acids are categorised under dissolved organic carbon (DOC) and at concentrations above 5 mg/L have an impact on water colour [2]. Though water colour is an important aesthetic property, the necessity for its removal has recently become more significant. Trihalomethane (THM) and haloacetic acids (HAA) are by-products of humic acid from conventional water treatment processes, such as chlorination and are known to be carcinogenic and hazardous to human health [3]. On a more positive side, investigations have found that the metal ions in the presence of humic acid have a much higher retention [4,5].

The removal of humic acid from aqueous solutions has been investigated by a number of researchers [6–12]. The application of ultrafiltration and other membrane-based techniques have shown potential for treatment of humic acid and other organic matter. That is the subject matter of this research.

The main objective of this research is to investigate the efficiency of ultrafiltration membranes in the removal of humic acid from river waters in New Zealand. At first water that has been deionised and distilled (known as milliQ water) will be used as the background water to which humic acid will be added. Pressure, membrane pore size (kDa) and initial humic acid concentration will be varied during the experimental stages to investigate their effects on humic acid removal efficiency and which combination would provide the best removal of HA.