Iranian Polymer Journal (2019) 28:391–401
https://doi.org/10.1007/s13726-019-00708-4

ORIGINAL RESEARCH

Nitrate removal from drinking water by PAN ultrafiltration assisted with cationic surfactants: evaluation of effective factors using response surface methodology

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Received: 26 November 2018 / Accepted: 26 March 2019 / Published online: 13 April 2019

Abstract

Polyacrylonitrile ultrafiltration membrane was used to remove nitrate from aqueous solution, assisted by variations in cationic surfactant type and structure [cetylpyridinium chloride (CPC) and hexadecyl trimethylammonium bromide (HTAB)]. This paper also studied the effects of membrane thickness (150, 200, 250 µm), nitrate concentration (40, 120, 200 ppm), and surfactant concentration (0.4, 5.2, 10 mM) on removal efficiency. To this end, the required experiments were designed through response surface methodology using design-expert 7.0.0 software. The results showed that CPC was generally more efficient than HTAB due to its hydrophilic head structure. Rejection was improved significantly by increasing surfactant concentration over critical micelle concentration (CMC), but a slight fall was observed for CPC at about 10 mM concentration of surfactant in all nitrate concentrations. The optimal condition was obtained at 8.18 mM CPC, 196.2 ppm nitrate and thickness of 160 µm, which resulted in rejection of 80.29% at 30th min of filtration with an average flux of 19.25 L/m^2 h. Increasing pressure showed a positive effect on rejection. Also, modified PVP-optimal membranes (160 µm) associated with different polyvinyl pyrrolidone (PVP) percentages by weight showed higher flux compared to an unmodified optimal membrane. Porosity and water content of optimal membrane were 49.9% and 82.56%, respectively, and surfactants rejection was always close to 100% over CMC.

Keywords Ultrafiltration · Surfactant · Cetylpyridinium chloride · Hexadecyl trimethylammonium bromide · Nitrate removal · Response surface methodology

Introduction

Nitrate contamination of drinking water is a serious concern around the world. In industrial areas, the nitrate concentration in rain water is usually over 5 mg/L and in surface waters it varies from 0 to 18 mg/L. The maximum contaminant level (MCL) of nitrate in drinking water allowed by the World Health Organization (WHO) is 10 ppm [1]. European Union has determined MCL of 50 ppm for nitrate in drinking waters though it does recommend nitrates to be less than 25 ppm [2]. Nitrate contamination level can increase from excessive usage of synthetic fertilizers, municipal runoffs and agriculture wastes [3].

Nitrate contamination of drinking water poses many threats to human health, especially for children. In infants under the age of 6 years, it can cause methemoglobinemia, diarrhea and acidose. In addition, nitrate can reduce to nitrite and combine with hemoglobin in blood and form methemoglobin, which causes a condition called blue-baby syndrome [4]. Among other health complications, stomach cancer has been widely cited [5]. There are some different methods for nitrate removal such as ion exchange, biological treatment, and membrane processes [6–8]. Most of these processes are difficult and expensive [3].

Membrane technology can be effectively used to meet the guidelines of WHO for drinking water. During the past two decades, the application of low-pressure processes such as ultrafiltration (UF) and microfiltration (MF) has attracted great attention to purify drinking water [9–11]. Moreover, UF membranes could be used in other applications such

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