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Effect of operating conditions in removal of arsenic from water by nanofiltration membrane

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Abstract

The removal of arsenic from synthetic waters and surface water by nanofiltration (NF) membrane was investigated. In synthetic solutions, arsenic rejection experiments included variation of arsenic retentate concentration, transmembrane pressure, crossflow velocity and temperature. Arsenic rejection increased with arsenic retentate concentration. Arsenic was removed 93–99% from synthetic feed waters containing between 100 and 382 μg/L As V, resulting in permeate arsenic concentrations of about 5 μg/L. Under studied conditions, arsenic rejection was independent of transmembrane pressure, crossflow velocity and temperature. In surface water, the mean rejection of As V was 95% while the rejection of sulfate was 97%. The co-occurrence of dissolved inorganics does not significantly influence arsenic rejection. The mean concentration of As in collected permeated was 8 μg/L. The mean rejection of TDS, total hardness and conductivity were 75, 88 and 75% respectively.

Keywords: Arsenic removal; Drinking water; Nanofiltration (NF); Operating conditions

1. Introduction

The United States Environmental Protection Agency (USEPA) maximum contaminant level (MCL), for arsenic was 50 ppb (μg/L) over 50 years ago. The arsenic MCL was lowered to 10 μg/L in a rule promulgated on January 22, 2001. Data had been under review by the USEPA for several years prior to issuing the new standard and seek an independent review of the science behind the standard and the cost as-

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sociated with implementing the new rule. The USEPA indicated that they believe that the arsenic standard needs to be revised and lowered below the current 50 μg/L level, but that they need to review if it is necessary to set the standard as low as 10 μg/L. The World Health Organization (WHO) has established a provisional arsenic limit of 10 μg/L because of the epidemiological evidence of arsenic carcinogenicity [1–4]. In Argentine, some of the drinking water sources contain more than this value [5,6] The concern over arsenic is especially severe because of the number of surface and groundwater systems that exceed the arsenic MCL.

Various technologies such as coagulation, filtration, lime softening, activated alumina, anion exchange, reverse osmosis have been studied to determine efficacy of arsenic removal [7]. Reverse osmosis has been identified as a best available technology for arsenic removal, but economic studies have shown it to be the most costly [8–9].

Developments in membrane technology have produced nanofiltration (NF) membranes with higher selectivity and increased water flux at much lower operating pressure. In addition, because arsenic is typically present in natural waters as a divalent oxyanion ($HAsO_4^{2-}$) [9–12], there has been much interest in the use of NF membranes which are know to be quite effecttive at removing divalent ions.

A limited number of studies have been performed to examine the removal of arsenic by NF membranes [9,13–16]. The results show that NF processes are effective for the removal of arsenic. Removal however depends upon operating parameters, membrane properties and the characteristics of the source water.

In this work experiments were performed using a NF module to determine the efficacy of As V retention from a synthetic solution under various operating conditions such as solution concentration, concentration factor (CF), trans--membrane pressure, recovery, crossflow velocity and temperature. Finally, experiments were performed to determine the removal of arsenic from surface water.

2. Materials and methods

2.1. Standards and reagents

All salt solutions were prepared fresh using reagent-grade chemicals dissolved in pure water. The arsenate, As V, standard was prepared from sodium salt heptahydrate, Na_2HAsO_4. $7H_2O$ (Mallinckrodt®), dissolved in pure water. Sodium bicarbonate solutions were prepared from $NaHCO_3$ (Fluka®).

2.2. NF membrane module

The NF membrane module is spiral wound thin film composite polyamide membrane (192-NF 300) manufactured by Osmonic Inc. The molecular weight cut off 180 Da. The NF membrane module is enclosed in an OSMO® 19E-HR 500-ECN-membrane housing. Each element is 2×39 in and has an active membrane surface of 1.5 m^2.

2.3. NF unit description

The unit used for carrying out NF experiments is reported in Fig. 1. It was equipped with a feed and permeate container, a pressure vessel containing the membrane module, a circulation and pressurization pump with a security valve two pressure gauges, a thermometer for temperature measurement in the circulation reservoir, a tap water heat exchanger for temperature control, two flow-meters on permeate and retentate exit pipers.

2.4. Sample analysis

Arsenic standard solution was prepared by appropriate dilutions of a 1000 mg/L stock solution (Merck) immediately before use.

A 0.6% (w/v) sodium borohydride solution (Aldrich Chemical Co.) was prepared in 0.5% (w/v) sodium hydroxide solution and was filtered through Whatman No. 42 filter paper to remove undissolved solids.