Available online at www.sciencedirect.com
ScienceDirect
Desalination 223 (2008) 85–90
DESALINATION
www.elsevier.com/locate/desal

Removal of inorganic charged micropollutants from drinking water supplies by hybrid ion exchange membrane processes

Svetlozar Velizarov*, Cristina Matos, Adrian Oehmen, Susana Serra, Maria Reis, João Crespo

CQFB / REQUIMTE, Department of Chemistry, FCT, Universidade Nova de Lisboa, P-2829-516 Caparica, Portugal
Tel. +351 21 294 8314; Fax +351 21 294 8385; email: velizarov@dq.fct.unl.pt

Received 20 December 2006; accepted 3 January 2007

Abstract

This study first illustrates the IEMB potential for the simultaneous removal of nitrate, perchlorate and bromate from drinking water. The removal of each of these pollutants to concentrations below the recommended levels for drinking water was successfully achieved. The initial development of the IEMB concept for the case of ionic mercury removal is then presented and discussed. For this purpose, appropriate cation exchange membranes were selected, and a suitable mixed microbial culture, capable of converting ionic mercury into elemental mercury, was obtained.

Keywords: Micropollutants; Perchlorate; Bromate; Ionic mercury; Ion exchange membranes; Donnan dialysis; Membrane bioreactors

1. Introduction

A number of charged inorganic compounds, e.g. anions such as perchlorate, bromate, arsenate, arsenite as well as cations, particularly cationic heavy metals have been found in potentially harmful concentrations in numerous water sources. The maximum allowed levels of these compounds in drinking water set by the World Health Organization are very low (within the ppb concentration range), thus the majority of them can be referred to as charged micropollutants. Their detection and removal from water represent both analytical and technological challenges. While the analytical advances (e.g. based on ICP-AAS or using Dionex HPLC systems) have highly improved the control of drinking water sources with respect to micropollutants,

*Corresponding author.

Presented at the conference on Desalination and the Environment. Sponsored by the European Desalination Society and Center for Research and Technology Hellas (CERTH), Sani Resort, Halkidiki, Greece, April 22–25, 2007.

doi:10.1016/j.desal.2007.01.217

the technologies available for their removal do not always meet the conditions that guarantee their complete removal in an efficient and environmentally friendly way.

The use of membranes is particularly attractive for separating trace ions between two liquid phases (purified and concentrated water streams) because many of the difficulties associated with their precipitation, coagulation or adsorption and subsequent phase separation can be avoided. Therefore, membrane technologies are successfully used nowadays for this purpose in drinking water treatment. The concentrated stream discharge and/or treatment, however, can be problematic in some cases. One of the recent trends to overcome these problems is towards using integrated process solutions, including the emerging issue of membrane bioreactors.

Following this trend, an integration of Donnan dialysis with simultaneous biological detoxification of a charged micropollutant — a new concept known as ion exchange membrane bioreactor (IEMB) — has been patented [1] and comprehensively experimentally studied for the case of water denitrification [2–4], theoretically modelled [5] and reviewed [6,7]. The main advantage of the simultaneous transport of a target ionic pollutant through a dense membrane followed by its bioconversion in an isolated compartment according to the IEMB concept is that it allows for the isolation of the microbial culture from the feed stream behind the membrane barrier, thus avoiding the contamination of the treated water with cells, metabolic by-products and excess carbon source. This, in turn, prevents the secondary contamination of the treated water. Therefore, the IEMB process is particularly attractive if high water quality is envisaged. Another advantage of the IEMB system is its simplicity and relatively low energy consumption (only necessary for pumping the solutions).

During the last few years, we have extended our systematic studies on the potential of the IEMB concept towards dealing with cases of other emerging water micropollutants such as oxyanions and heavy metals. The sources and human health effects of perchlorate are being hotly debated, especially in the U.S., where this strong oxidizer has percolated into groundwater near military installations and has been released by fireworks and roadside flares. It also occurs naturally in Chilean nitrate deposits, which were used extensively for fertilizer until the 1950s, and also results from atmospheric deposition. The chemical has surfaced in milk, lettuce, and other foods around the world. Perchlorate at high doses blocks the uptake of iodide in the thyroid, and this interferes with the production of thyroid stimulating hormones (TSH). Current US EPA regulations adopted the NRC reference dose for perchlorate of 0.7 μg per kilogram body weight per day. California has proposed a 6 ppb maximum contaminant load in drinking water, and Massachusetts has set its regulation at 2 ppb (Science News – October 24, 2006).

Bromate at levels ranging from 0.4 to 60 ppb may be found after ozonation of water containing background bromide [8]. This oxyanion is highly soluble, stable in water, and difficult to remove using conventional treatment technologies. Analytical advances have recently led to detection of bromate contamination in both surface and groundwater, which has provided an additional requirement for bromate remediation. Bromate is classified as a possible human carcinogen, and maximal allowed contaminant levels of 10 to 25 ppb are now implemented by many national drinking water regulations.

Besides oxyanions such as perchlorate and bromate, other charged micropollutants have also been found in drinking water supplies at potentially harmful concentrations, particularly heavy metals. Mercury is the most highly toxic heavy metal [9], and is a bioaccumulative toxin that attacks the central nervous system and endocrine system. Mercury exposure over long periods of time can result in brain damage and