Available online at www.sciencedirect.com
ScienceDirect
Reactive & Functional Polymers 67 (2007) 1635–1642
REACTIVE & FUNCTIONAL POLYMERS
www.elsevier.com/locate/react

Donnan dialysis of borate anions through anion exchange membranes: A new method for regeneration of boron selective resins

Marek Bryjak [a,*], Gryzelda Poźniak [a], Nalan Kabay [b]

[a] *Chemistry Department, Wroclaw University of Technology, 50-370 Wroclaw, Poland*
[b] *Chemical Engineering Department, Ege University, 35100 Izmir, Turkey*

Available online 26 July 2007

Abstract

The studies on sorbent regeneration by Donnan dialysis have been presented. Two kinds of anion exchange membranes were evaluated: microheterogenous, based on interpenetrating polymer network and homogenous prepared from modified homopolymer. The studies revealed that sodium chloride is the salt that forced borate transport more effectively than sodium sulfate does. Both membranes showed similar efficiency in borate transport. It was shown that the particle diffusion within resin particles was the limiting process parameter for regeneration of boron selective resins.

Keywords: Donnan dialysis; Borate; Anion exchange membrane; Sorbent regeneration

1. Introduction

Boron is widely distributed element in the nature. Due to its high affinity to oxygen it usually appears in the form of borate. Sometimes it turns to such species as polyborates, complexes with transition metals and fluoroborate compounds [1]. There are two origins of borate present in surface water: it is created by natural or anthropogenic factors [2]. The first includes weathering of rocks, leaching of salt deposits and rainfalls close to sea-shore while the second is mostly related to human activity. Boron can be discharged in drainage of coal mines or come from landfills of mining industry. The other sources are wastes of glass and ceramic manufactures, wire industry or manufactures of leather or carpets. Production of some photographic chemicals, cosmetics, detergents or fire-protecting fabrics is boron related also. Boric acid that shows fungicidal and bactericidal properties is used to impregnate wood, as agricultural disinfectant and food preservative. Boron is also a component of welding rods or high-energy fuels [3]. Some amounts of boron are now monitored in the municipal sewage that originates from household wastes [4]. Today, when our civilization is facing the water shortage problem the attention is to the use of sea and brackish waters. Water desalination process has turned to be the flywheel of membrane technologies. However, permeate obtained after the first stage of reverse osmosis plant, RO, even when the plant is

* Corresponding author. Fax: +48 71 320 2987.
E-mail address: marek.bryjak@pwr.wroc.pl (M. Bryjak).

1381-5148/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.reactfunctpolym.2007.07.028

equipped with the high rejection membranes, does not meet usually the recommendation of the World Health Organization for boron level; the limit of 0.3 mg/L. In such situation, the RO permeate has to pass additional treatment to reduce concentration of boron. Among several used methods, ion-exchange on specially prepared sorbents seems to be the most popular.

Simonnat et al [5] has reviewed the methods of boron removal from drinking water. Among several of them, she has pointed at sorption at boron selective resin, BSR, as the most effective way. However, the method has its own drawbacks: the operational costs of sorption and regeneration processes, cost of sorbent and problems with waste management. It seems that the use of sorption membrane filtration hybrid opens a new perspective for water deboronation [6]. The whole process is divided on two steps: boron adsorption on suspended micro-particles of BSR followed by complex concentration on a microfilter and sorbent regeneration by classical method – elution of boron by acid followed by sorbent rinsing with water. The idea of sorption membrane filtration hybrid is shown in Fig. 1 and is described elsewhere [7]. This paper presents our attempts to use Donnan dialysis, DD, for the sorbent regeneration step. That approach allows us to check possibility for the use of high saline brine coming from the fist stage RO to sorbent regeneration purpose. The literature refers to similar approach when extraction of Al(III) cations from a municipal sludge was found to be effective by Donnan dialysis process [8].

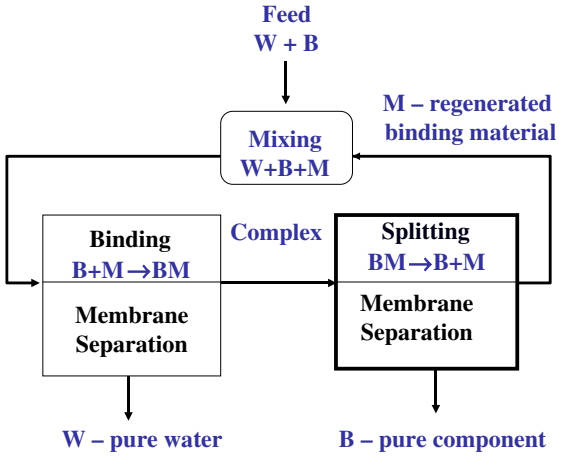

Fig. 1. Scheme of adsorption membrane filtration hybrid.

The goal of our investigations was to check if slurry regeneration of boron selective resin loaded with boron is possible and what kind of membrane is required for that process.

2. Experimental

2.1. Materials and methods

All chemicals were reagent grade and were purchased from Merck. MiliQ water was used for preparation of solutions and for membrane rinsing.

2.1.1. Membranes

Three membranes were used for the studies.

(1) AESD-2 interpenetrating polymer membrane (IPN) is used in electrodialysis and Donnan dialysis. It is the interpolymer of styrene-co-divinylbenzene (1% wt) in polyethylene. It is obtained by swelling of polyethylene grains with styrene and divinylbenzene followed by monomers polymerization in the polymer matrix. After that interpolymer is processed and shaped in an extruder die. Finally, the aromatic part of a foil is chloromethylated and reacted with dimethylethanoloamine (DMEA) to give AESD-2 membranes. The detailed description of the used method is described elsewhere [9,10]. The prepared membrane had the following properties: ion-exchange capacity 1.11 mmol/g dry polymer, water uptake 28%, and thickness 180 μm. Polyelectrolyte in the PE matrix forms the structure similar to Nafion membranes – 30–50 nm domains are connected by narrow – 2–5 nm channels. That membrane is called IPN membrane in this paper.

(2) Non-porous membrane obtained from poly(phenylene oxide), PPO. The membrane was prepared by casting PPO/dimethylformamide solution on glassy pane followed by slow evaporation of solvent. Temperature was kept as low as 40 °C during the whole process. The foil was chloromethylated and modified with DMEA to obtain membrane with ion-exchange capacity of 1.77 mmol/g dry polymer, 80% water uptake and thickness of 40 μm. The method of membrane preparation is described elsewhere [11]. This membrane is called gel-like membrane.