



Phosphate pre-concentration from municipal wastewater by selectrodialysis: Effect of competing components



Anh T.K. Tran^{a,b,*}, Yang Zhang^c, JiuYang Lin^a, Priyanka Mondal^a, Wenyan Ye^a,
Boudewijn Meesschaert^d, Luc Pinoy^e, Bart Van der Bruggen^a

^a Department of Chemical Engineering, proCESS – Process Engineering for Sustainable Systems, KU Leuven, W. de Croylaan 46, B-3001 Leuven, Belgium

^b Faculty of Chemical and Food Technology, HCM University of Technical Education, Viet Nam

^c Department of Civil and Environmental Engineering, University of Illinois at Urbana-Champaign, Urbana 61801-2352, USA

^d Department of Microbial and Molecular Systems, Cluster for Bioengineering Technology, KU Leuven, Technology Campus Ostend, Zeedijk 101, B-8400 Oostende, Belgium

^e Department of Chemical Engineering, Cluster Sustainable Chemical Process Technology, KU Leuven, Technology Campus Ghent, Gebroeders Desmetstraat 1, B-9000 Ghent, Belgium

ARTICLE INFO

Article history:

Received 22 July 2014

Received in revised form 17 November 2014

Accepted 21 November 2014

Available online 29 November 2014

Keywords:

Phosphate concentrating

Selectrodialysis

Wastewater

Competing ions

ABSTRACT

The effect of competing ions in wastewater on the phosphate pre-concentrating efficiency by selectrodialysis was demonstrated in this study. Nitrate, bicarbonate and sulphate are three ions frequently present in wastewater. An inhibition of these ions to the phosphate concentrating efficiency was found to occur initially, but if the system runs for a longer time, the effect disappears. In the presence of nitrate, bicarbonate and sulphate, the phosphate concentrating efficiency in the product was significantly reduced from 188% to 78% after 210 min, but this could be recovered to 161% after 300 min. In addition, when operating selectrodialysis with synthetic municipal wastewater, phosphate was concentrated in the product with a twofold concentration compared to the initial concentration in the wastewater. Scaling on the cation exchange membrane and monovalent selective anion exchange membranes was observed during the selectrodialysis process when carrying out the experiment with synthetic municipal wastewater, but the membranes were almost completely recovered after a simple acid cleaning with 0.1 M HCl solution for 1 h. The present study indicates that selectrodialysis successfully concentrates phosphate from wastewater in the product stream, which makes a subsequent crystallization process viable to recover phosphate from wastewater.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

Due to the scarcity and depletion of natural resources, wastewater should be considered as a “renewable” resource, from which valuable components can be recovered [1]. Phosphorus (P) is one of the essential and limited elements, therefore “phosphate recovery” from wastewater is now considered an important aspect in sustainable development [2]. The most developed technique that can be applied to recover phosphate is precipitation/crystallization as struvite and calcium phosphate [3–5]. However, this technology still has drawbacks since low feed concentrations lead to low supersaturation levels and low efficiency. The minimum P concentration required for good precipitation is 50 mgP/L at neutral pH

[6], while the concentration of phosphate in municipal wastewater is low (from 18.5 to 48.3 mgP/L) [7]. Our previous study [8] confirmed that the phosphate removal efficiency by crystallization in a pellet reactor increased from 9.7% to 76.8% when the initial concentration increases from 0.54 mM to 4.5 mM. Consequently, to achieve a high recovery efficiency, new techniques are to be developed in order to concentrate more phosphate prior to the precipitation process.

Adsorption [9,10], ion exchange [11,12] and nanofiltration [13,14] are three common methods to concentrate and recover phosphate from wastewater. However, adsorption and ion exchange need a regeneration procedure to release the phosphate from adsorbents and ion exchange resins which leads to a higher operational cost and a more complicated process. Additionally, scaling and fouling often occur on membrane surfaces when using nanofiltration to recover phosphate from wastewater. One of the most promising technologies to overcome these constraints is electrodialysis, a non-pressure driven membrane process in which ion exchange membranes are arranged under an electrical field [15]. It

* Corresponding author at: Department of Chemical Engineering, Process Engineering for Sustainable Systems, KU Leuven, W. de Croylaan 46, B-3001 Leuven, Belgium. Tel.: +32 16 3 22716; fax: +32 16 3 22991.

E-mail addresses: anh.tran@cit.kuleuven.be (A.T.K. Tran), bart.vanderbruggen@cit.kuleuven.be (B. Van der Bruggen).

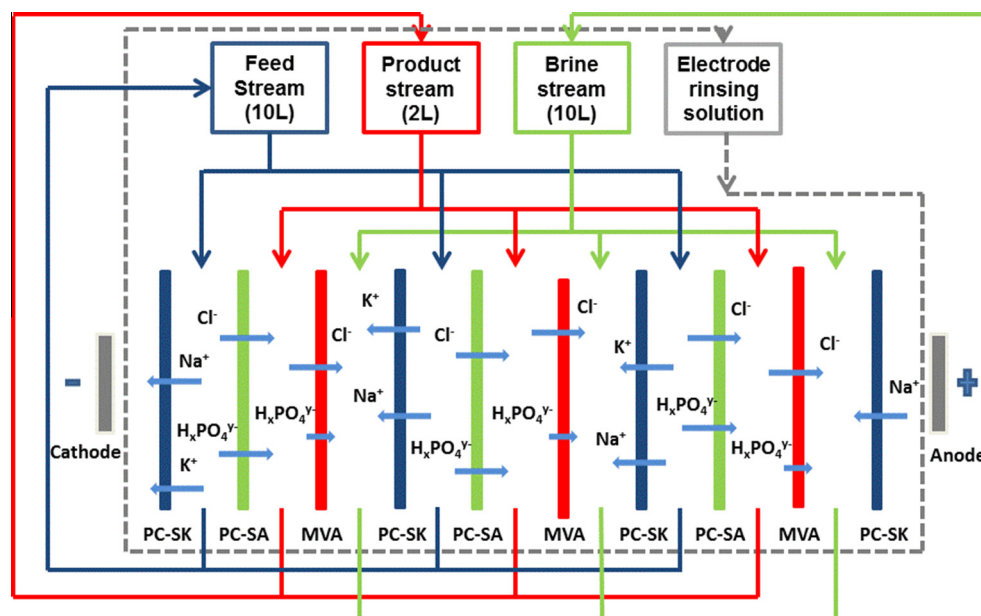


Fig. 1. Cell configuration of electrodialysis with monovalent selective anion exchange membrane (Adapted from [8]).

is used for desalination, concentration of ions from a solution [16], and production/recovery of acid and base from corresponding salts with bipolar membranes [17–19]. Recently, electromembrane processes have been studied to recover phosphate from nanofiltration concentrate by using an electrophoretic system with one cation exchange membrane between a cathode and an anode. The increase in pH at cathode due to the reaction: $4 \text{H}_2\text{O} + 4\text{e}^- \rightarrow 4 \text{OH}^- + 2 \text{H}_2$ caused a shift from H_2PO_4^- ions to mainly HPO_4^{2-} or PO_4^{3-} ions, which led to higher supersaturation and therefore precipitation of calcium phosphate occurred [20]. In addition, electrodialysis has also been used to separate multivalent ions from monovalent ions in an aqueous solution. Sulphate ions were separated from a mixture containing chlorides and sulphates by integrating divalent low-permeable anion exchange membranes in an electrodialyzer [21] and by selectrodialysis in which a monovalent selective anion exchange membrane is positioned between the anion and cation exchange membranes. This yields three compartments: feed, product with high concentration of sulphate, and brine [22]. Selectrodialysis was also used for pre-concentrating phosphate from potato anaerobic wastewater and the product of this process was used as the influent of a struvite reactor to recover phosphate [23].

Since wastewater contains a variety of ionic species, a key consideration is the competitive impact of these ions on the phosphorus concentration efficiency. Sulphate, bicarbonate and nitrate are the main inorganic anionic species present in wastewater expected to have an effect on the feasibility of phosphate fractionation/concentration by selectrodialysis, because of the possible competition in migration from feed to product stream and also because of the multiple charge of sulphate and bicarbonate (divalent for sulphate, monovalent for bicarbonate but changing to divalent at high pH). Their effect on the phosphate concentrating efficiency of selectrodialysis has not yet been investigated. Previous studies with a similar process proved the feasibility of phosphate concentration in synthetic water with phosphate and chloride [8] and in real anaerobic wastewater [23]. The present study investigates the impact of competing ions on the phosphate concentrating efficiency using synthetic water with low phosphate concentration. In addition, synthetic municipal wastewater containing a high concentration of calcium and magnesium, which easily cause scaling on the

membrane surface, was also studied. Finally, long run experiments were carried out to test the stability of the system. Studying these parameters helps further understanding the factors likely to influence the performance of such a selectrodialysis system when applied to pre-concentrate phosphate at full scale wastewater treatment plants.

2. Materials and methods

2.1. Solutions

Synthetic water and synthetic municipal wastewater were prepared from the following chemicals: KH_2PO_4 (UPC, Belgium), $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ (Chem-Lab, Belgium), and NaCl (BDH Prolabo, Belgium) dissolved in de-ionized water with the concentration described in Table 2. The pH was adjusted to the desired value by using either a 6 M NaOH solution prepared from solid NaOH (Fisher Scientific, UK) or HNO_3 56% (Chem-Lab, Belgium) and HCl 37% (Fisher Scientific, UK).

2.2. Experimental setup

A lab-scale, three-compartment ion exchange membrane electrodialysis system (the selectrodialysis unit) was used to perform the experiments. The ED stack (ED-64-004) was provided by PCell GmbH, Germany. The configuration is described elsewhere [22]. Three pieces of anion exchange membranes (PC-SA), three pieces of monovalent selective anion exchange membranes (PC-MVA) and four pieces of cation exchange membranes (PC-SK) were used in the stack, each with an effective surface area of 64 cm^2 , dividing the stack into four compartments: electrode rinsing, feed, product, and brine compartment (Fig. 1). Due to the applied electrical field, the anions (Cl^- , SO_4^{2-} , HCO_3^- and $\text{H}_x\text{PO}_4^{y-}$) move across the PC-SA membrane while the cations (Na^+ , K^+ , Ca^{2+} and Mg^{2+}) move across the PC-SK membrane. Since PC-MVA membranes were placed between PC-SA and PC-SK and the pH of the product was kept at 12, the multivalent ions CO_3^{2-} , SO_4^{2-} , $\text{H}_x\text{PO}_4^{y-}$ should be kept in the product compartment (Fig. 1). The equipment consisted of four separated circuits for the feed, the product, the brine and the elec-

Download English Version:

<https://daneshyari.com/en/article/640654>

Download Persian Version:

<https://daneshyari.com/article/640654>

[Daneshyari.com](https://daneshyari.com)