Environment Protection Engineering

Vol. 31 2005 No. 3–4

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THE CONCEPT OF UTILIZING A BORON-CONTAINING LANDFILL LEACHATE BY MEANS OF MEMBRANE TECHNIQUES

Landfill leachate characterized by high concentration of boron and heavy metals causes serious environmental problem at Tarnowskie Góry (Poland). Typical elements, their concentration and ionic composition in wastewater are as follows: boron, up to 80 mg/dm^3; Fe, 0.022 mg/dm^3; Zn, 25 mg/dm^3; Cd, 0.16 mg/dm^3; Mn, 4.2 mg/dm^3; Cu, 0.01 mg/dm^3; Pb, 0.75 mg/dm^3; Sr, 4.44 mg/dm^3; Ni, 0.04 mg/dm^3; Zr, 0.008 mg/dm^3 and Cr, 0.004 mg/dm^3; Na^+, 820 mg/dm^3; Cl^-, 320 mg/dm^3; SO_4^{2-}, 1130 mg/dm^3; Ca^{2+}, 37 mg/dm^3; Mg^{2+}, 10 mg/dm^3 at TDS of approximately 2.5 g/dm^3. A rational utilization of such a complex leachate requires many effective steps, including aeration, alkaline precipitation of heavy metals, activated carbon adsorption, softening and finally boron removal.

In this work, the strategy of the above-mentioned leachate utilization by means of membrane separation methods was discussed. An effective boron removal and concentrated boron solution preparation are of prime importance in the reduction of the cost of concentrate disposal. Based on our previous results we concluded that boron concentration might be efficiently reduced by means of RO or ED only at a high pH of leachate. Such a high alkalinity constricts a proper leachate pretreatment, i.e. heavy metal removal and chemical or membrane softening of leachate. Based on the aforesaid conclusions the concept of utlization of the Tarnowskie Góry landfill leachate was presented.

Keywords: *boron removal, landfill leachate utilization, electrodialysis, nanofiltration, reverse osmosis*

1. INTRODUCTION

Boron is a commonly known water contaminant that affects the reproductivity of living organisms [1]. Due to its adverse action Polish and international regulations (WHO, EU) [2]–[5] strictly limit its content in drinking water and water discharged to environment.

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The effectiveness of different methods of membrane desalination in boron removal has been recently considered [6]–[14]. It has been shown that the efficiency of boron removal in reverse osmosis (RO) and electrodialytic (ED) systems is mainly limited by pH of feedwater. Furthermore, it has been proven that boron cannot be effectively removed using classic membrane desalination techniques because of the complexity of boric acid dissociation at neutral pH. Therefore it is commonly reported that many special efforts devoted to an efficient boron removal must be considered when designing desalination technology for boron-rich water. The commonly presented efforts are: operating RO or ED systems at high pH of feedwater (close to 10), multistage desalination and/or applying ion-exchange resin to remove boron from RO permeate.

2. THE OBJECTIVE OF THE WORK

In the present work, the authors discussed the concept of utilizing a boron-rich landfill leachate by means of membrane techniques. A landfill leachate at Tarnowskie Góry was investigated. The concepts presented were based on the authors' previous research [15], [16] as well as on an available literature.

2.1. DESCRIPTION OF THE LEACHATE TESTED

At Tarnowskie Góry (Poland) landfill leachate, which contains considerable amounts of heavy metals and boron in the form of boric acid, poses a serious ecological problem. A chemical composition of this leachate is given in the table. It can be clearly seen that some elements, e.g. boron, exceed the limits imposed on the water discharged to the environment.

Table

Chemical composition of the leachate in question

Constituents	Concentration, mg/dm^3
1	2
B	20–80
Na	820
Ca	37
Mg	10
Cl^-	320
SO_4^{2-}	1130
Fe	0.022
Zn	25
Cd	0.16

1	2
Mn	4.2
Cu	0.01
Pb	0.75
Sr	4.44
Ni	0.04
Zr	0.008
Cr	0.004
TDS	ca. 2500

Presently the landfill at Tarnowskie Góry is being utilized in a multistage system presented schematically in figure 1. In general, there are two treatment steps:

• Step 1. Removal of heavy metals by alkaline precipitation, coagulation, filtration and finally activated carbon adsorption.

• Step 2. Boron (in the form of oxoborate) removal from alkaline solution by using a boron-selective ion-exchange resin.

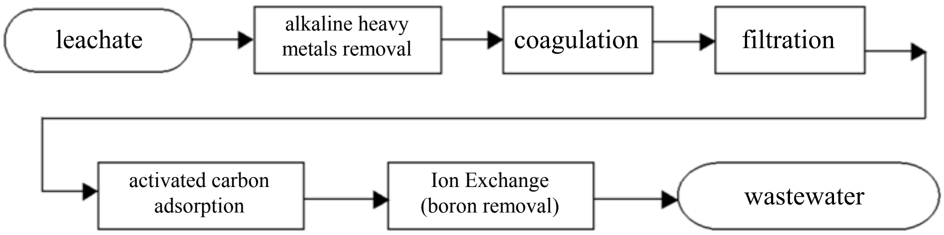

Fig. 1. Scheme of the Tarnowskie Góry plant for the treatment of landfill leachate

In the above treatment scheme, boron removal (step 2) was found to be the most incommodious, mainly because of its relatively high concentration (see the table). Such high boron content makes the regeneration of ion-exchange resin extremely difficult, because it increases the volume of regeneration eluate and the cost of boron disposal.

In the authors opinion, a high cost of boron disposal can be solved by carrying out membrane processes. Therefore the research that intensified the application of reverse osmosis and electrodialysis was undertaken. High effectiveness of boron removal and low cost of utilization of the boron removed were set to be the main goals of this work. If it were possible to concentrate a pure sodium borate (borax) or boric acid solution, this would be of benefit, since this product might be further sold, e.g. as an artificial fertilizer, thus decreasing, to a large extent, the utilization costs.

3. DESCRIPTION OF THE UTILIZATION CONCEPT

In the past, we carried out a set of experiments on boron removal from the Tarnowskie Góry landfill leachate using ion-exchange [15] and reverse osmosis membranes [16]. It was found that boron might be efficiently removed from this type of leachate by means of electrodialysis and reverse osmosis, provided that pH of this leachate is relatively high (≥ 10). However, special effort must be made to loosen Polish regulations imposed on waters discharged directly to the environment.

Electrodialytic boron removal was reported in paper [15]. Its authors treated the leachate from the Tarnowskie Góry landfill in two steps: 1. Demineralization carried out in slightly acidic medium. 2. Boron removal using CMS and ACS Neosepta univalent permselective membranes. In the first step, the leachate was partially desalinated in slightly acidic medium. Most chlorides (92%), sulfates (67.5%) and calcium (80%) were removed at a very small boron removal (0.8%). In the second step with shifted pH, univalent permselective membranes enable high, compared to that reported by other authors, boron removal efficiency (26.7%) and high boron fluxes (95.0 $\mu g/cm^2$ h). These two values led the authors to the conclusion that the above-described system might be considered a potential method of boron removal.

The reverse osmosis tests presented in [16] showed that the boron might be efficiently removed using these membranes at pH close to 11; however, in that case only up to 50% recovery might be achieved because of boron content higher than 1 mg/dm^3 being measured at higher recovery levels. Therefore a two- or three-stage RO system operated in alkaline medium was found to be suitable for boron removal to the level desired. Furthermore a high calcium level and the corresponding high potential of calcium carbonate and calcium sulfate for scaling were reported. Since the potential of $CaCO_3$ and $CaSO_4$ for scaling was suspected to hinder the operation of RO modules, especially in highly alkaline medium, a chemical or membrane softening as the pretreatment step was found to be requisite. A more detailed analysis of the chemical composition of the leachate tested led to the conclusion that sodium carbonate alkaline precipitation softening, addressed to remove calcium, might be reasonable. In that case, the precipitant allows us to remove calcium and to shift the pH of leachate to the level desired.

Based on the above experimental results the concept of utilizing the membrane used for the treatment of leachate from the landfill at Tarnowskie Góry is proposed. It is schematically presented in figure 2. Alkaline leachate after heavy metal removal (see figure 1) is acidified to pH 6 and directed to a diluate chamber of ED unit operating under partial desalination conditions (ED, step 1). In this unit, almost 95% of TDS are removed. In step 1, both partial desalination and softening take place, since most calcium, magnesium and sulfates are removed. The step of partial desalination is mostly addressed to enable a subsequent RO operation in highly alkaline medium, where there is no risk of $CaCO_3$ and $CaSO_4$ scaling. Then the softened leachate is alkalized using sodium (potassium) hydroxide to pH 10 or higher and directed to multistage RO system. This RO system proposed should be designed in such a way that concentrated sodium borate (borax) or boric acid solution is obtained simultaneously with permeate which adjusts the water discharged to environmental limits. The concentrated boron solution obtained is a utilization benefit. Borax and boric acid can constitute a valuable product, e.g. artificial fertilizer, thus reducing, to a large extent, utilization costs. Furthermore, part of the RO permeate may feed the ED unit concentrate stream as presented in figure 2. This should also result in cutting ED cost.

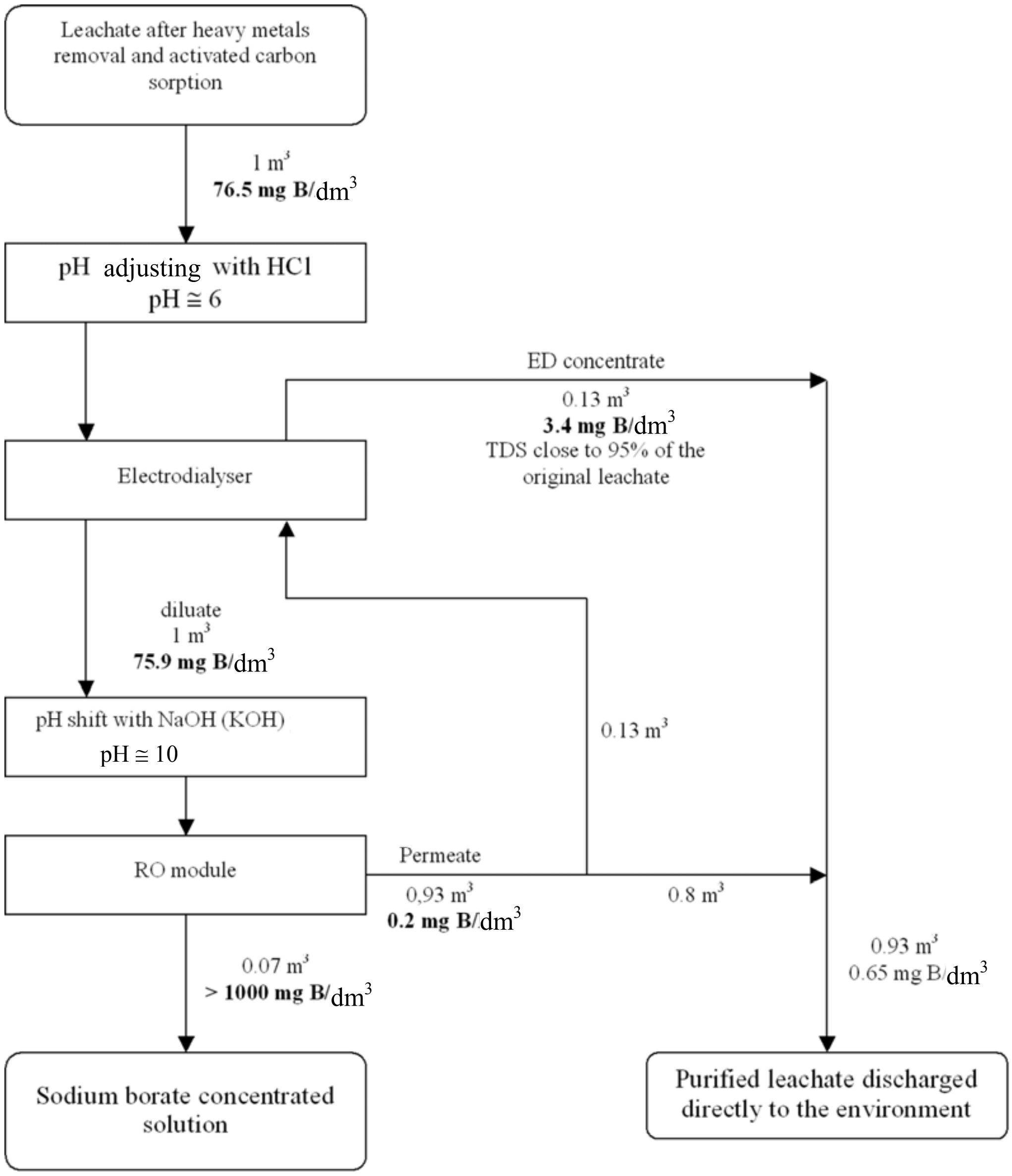

Fig. 2. Schematic representation of the utilization system proposed to treat the leachate from the Tarnowskie Góry landfill using electrodialysis and reverse osmosis

4. CONCLUSIONS

Based on the authors laboratory results reported previously, the concept of utilization of the leachate from the Tarnowskie Góry landfill was presented. The concept supposes the use of electrodialysis for partial desalination of leachate and softening step followed by multistage reverse osmosis in the feedwater of high alkalinity. The RO system proposed should be designed in such a way that concentrated sodium borate (borax) or boric acid solution is obtained simulteneously with permeate which allows the waters discharged to environment to approach the limits. Production of the concentrated solution of boron was found to be a utilization benefit, since borax and boric acid might constitute a valuable product, e.g. an artificial fertilizer, thus decreasing, to a large extent, utilization costs. Furthermore, part of the RO permeate might feed the ED unit, decreasing the cost of ED.

ACKNOWLEDGEMENT

This work was supported by the Polish Minister of Science and Ministry of Scientific Research and Information Technology, grant No. 3 T09B 084 28, over 2005–2008 period.

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