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Electrodialytic recovery of phosphorus from chemically precipitated sewage sludge ashes

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Abstract: Phosphorus scarcity requires improved recover and reuse of urban sources; the recycling of this nutrient from sewage sludge has become increasingly important in the last years. Using an innovative electrodialytic process, the present study shows the potential for P separation from Fe and Al precipitated sewage sludge ash using this technique, with a recovery rate of around 70%. Furthermore, heavy metals were removed from the phosphorous fraction, producing a pure and safe phosphorus source in the end.

Keywords: Phosphorus; Electrodialysis; Sewage sludge ash

Introduction

Phosphorus (P) input in agriculture is currently dependent on fertilizers manufactured from phosphate rock. However, the reserves of this mineral are estimated to last for a period oscillating from 50-100 (Cordell et al., 2009) to 300-400 years (Dawson et al., 2011), depending on the study. Moreover, phosphate rock usage is the main contributor of the accumulation of elements like cadmium (McBride, 2001) and uranium (Taylor, 2007) in agricultural soils. For these reasons, P recycling from secondary resources, like sewage sludge, has gained much attention over the last decade (Sartorius et al. 2012). Major concerns which limit sewage sludge direct use on agricultural fields are its heavy metal content and potential unwanted organic pollutants. Another difficulty is the limited plant-availability of P, when it is precipitated with Al and Fe salts in the wastewater treatment plant to avoid eutrophication of natural water system recipients.

Thermal processes like incineration (Donatello et al., 2013) and gasification (Thomsen et al. 2015) can lead to the removal of organic contaminants from sewage sludge, but additional steps are required to separate P from heavy metals and ensure its bioavailability in the resulting ashes. So far, most studies focus on chemical P-extraction from sewage sludge ash (SSA) or its thermal treatment (Sartorius et al. 2012). Electrodialysis (ED) has also been investigated as a technology to recover P from SSA, obtaining the lowest success for ashes with high content of Fe-P and Al-P bounds, like gasification ashes (Parés Viader et al., 2015) and Al-precipitated SSA (Ottosen et al., 2014), respectively. The present research focuses on achieving a higher recovery of P from SSA, with high content of Fe-P and Al-P bounds, using an innovative ED process.

Material and Methods

The ED process used in the present research is based on the setup used in previous work (Figure 1) by Parés Viader et al. (2015) and Ebbers et al. (2015), and adapted to treat materials with high content of Fe-P and Al-P bounds. The SSA used in this work originates from the gasification of chemically precipitated sewage sludge equivalent to Parés Viader et al. (2015) work, with high presence of Fe-P bounds. The duration of the treatment was 6 days and the electrical density used was around 1 mA/cm^2 .

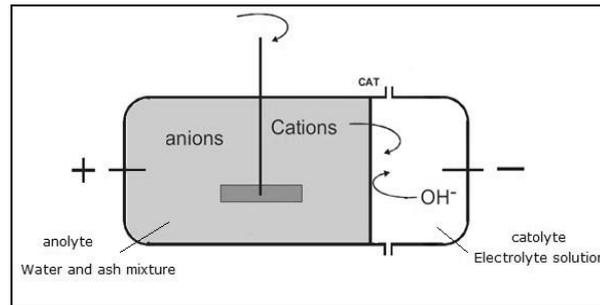


Figure 1: Schematic view of a 2-compartment ED cell. CAT: cation-exchange membrane.

Results and Conclusions

P was recovered in an acidic liquid solution, with a concentration of around 1.3 g/L of P, at a rate of 70%; this is considerably higher than the separation achieved in a previous research with the same SSA, which was around 30% (Parés Viader et al., 2015). Results showed smaller mass ratio of Al/P and Fe/P in the resulting solution than in the initial SSA (Table 1). That is an important characteristic if P is used in the manufacturing of fertilizers, in order to ensure a high plant-availability. Furthermore, the heavy metal to P mass ratio of the solution was below the initial values of the untreated SSA and, for Cr, Ni and Zn, below the ones found in wet process phosphoric acid from Morocco (WPA, Table 1). Therefore, it can be concluded that the ED process is an effective technology to recover most P from SSA with high content of Fe-P (and potentially Al-P) bounds including purification from Al, Fe and heavy metals.

Table 1 P, Al, Fe and heavy metals to P mass ratio comparison in the initial gasification SSA, the liquid solution after ED treatment and WPA.

Element	ED liquid solution	Initial SSA	Morocco WPA(Gilmour, 2014)	Ratio
Al	0.024	0.4	0.0009	g/g P
Fe	0.024	2.0	0.0055	g/g P
Cr	<15	1,300	1,442	mg/kg P
Cu	150	5,800	73	mg/kg P
Ni	<15	1,100	289	mg/kg P
Pb	48	1,400	4	mg/kg P
Zn	840	35,000	3,073	mg/kg P

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