Valorization of bottom ash from municipal solid waste incineration: Recovery of copper by electrowinning

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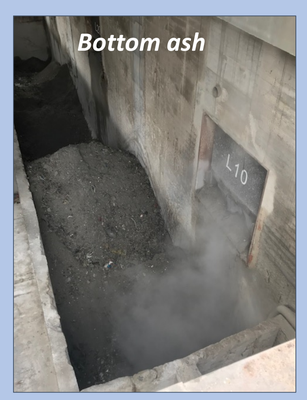
INTRODUCTION

Municipal solid waste incineration (MSWI) processes generate 0.2 tonnes of bottom ash (BA) per tonne of MSW. These bottom ashes contain significant quantities of metallic species that can be leached into the environment [1]. For that, the reduction of metal content would allow to use them in different applications such as road bases, cements or concretes [2].



The aim of this work was to study the feasibility of copper recovery from bottom ashes by a combination of two processes: solid-liquid extraction and electrowinning (EW). Therefore, firstly, the leaching of metallic elements (e.g. Cu, among others) was carried out. Then, this leachate was used as feed stream in the electrochemical process (see Figure 1). Moreover, different operating parameters were investigated to achieve maximum copper recovery: current density, electrodeposition time, initial Cu concentration, pH and presence or absence of Fe in the solution.

MATERIALS AND METHODS

a) Leaching process:
- 50 g of BA in 1 L of 1M H_2SO_4
- Magnetic stirring for 24 h

b) Fe precipitation process:
- Fe removal increasing pH up to 3.7
- Use of four reactive agents: NaOH, $CaCO_3$, NH_3 and $Ca(OH)_2$

c) Cu electrowinning process:
- Leachate was used as feed stream (containing Al, P, Zn, Ca, Fe, Mg, Na, K, Cu, Mn, Pb, Cr, Ni, Cd, As, Y, Ag, Hg, Au and rare earth elements)
- Electrochemical cell was composed of: one Ti/IrO_2 anode and two 304 stainless steel cathodes
- Cathode active surface of 56 cm^2
- Keysight N5746A for system power supply
- Room temperature (25°C)
- Tested variables: current density (100, 200 and 300 A/m^2), electrodeposition time (from 2 to 7 h), initial Cu concentration (0.1, 0.5 and 1 g/L), pH (0.5 and 1.5) and presence or absence of Fe in the solution

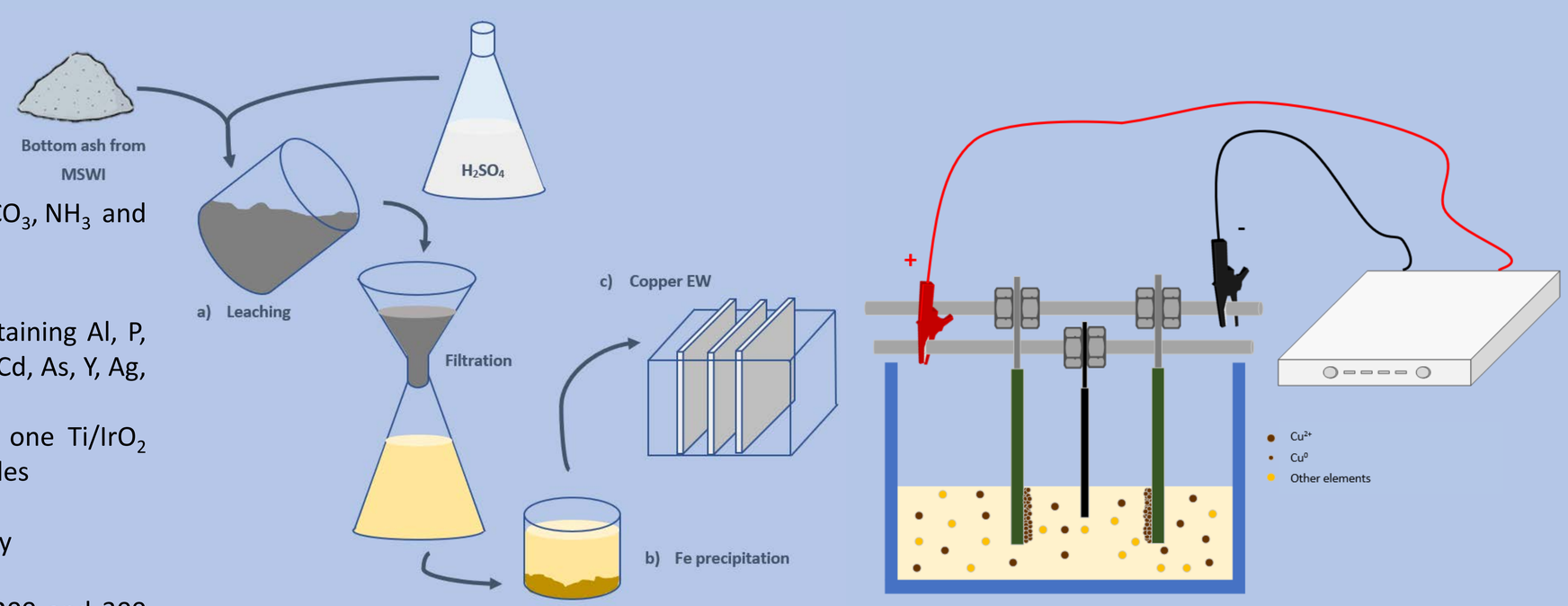


Figure 1. *Schematic representation of the proposed EW process.*

RESULTS AND DISCUSSION

Precipitation process

By means of precipitation it was possible to remove most of Fe from the leachate (Table 1). Meanwhile, the other elements present in solution were not removed. Ammonia was the reagent that removed most of Fe (95 – 97%) and reducing the Cu concentration by only 8 – 20%.

Table 1. *Fe and Cu removal results by each precipitation method.*

Precipitation method	Fe removal (%)	Cu removal (%)
2M NaOH and 1 mL H_2O_2	97%	44%
2M NaOH and 5 mL H_2O_2	97%	44%
8M NaOH and 1 mL H_2O_2	96%	22%
8M NaOH and 5 mL H_2O_2	93%	23%
$CaCO_3$ (14.8 g)	46%	0%
$CaCO_3$ (15.3 g)	43%	0%
8M NH_3 and 1 mL H_2O_2	**97%**	**20%**
8M NH_3 and 5 mL H_2O_2	**95%**	**8%**
$Ca(OH)_2$ (5.8 g)	45%	0%
$Ca(OH)_2$ (5.5 g)	28%	0%

Electrowinning process

According to the experimental results, the precipitation of Fe before the electrowinning process improved the extraction (98.3 to 99.7%), recovery (89.2 to 92.4%), concentration factor (44.6 to 46.2) and, especially, purity (91.8 to 98.6%) values (Figure 2). As explained before, the leachate from BA contained a multitude of elements. However, their concentration remains constant during copper EW process, except for Cu which decreases, indicating the selectivity of Cu during the process (Figure 3).

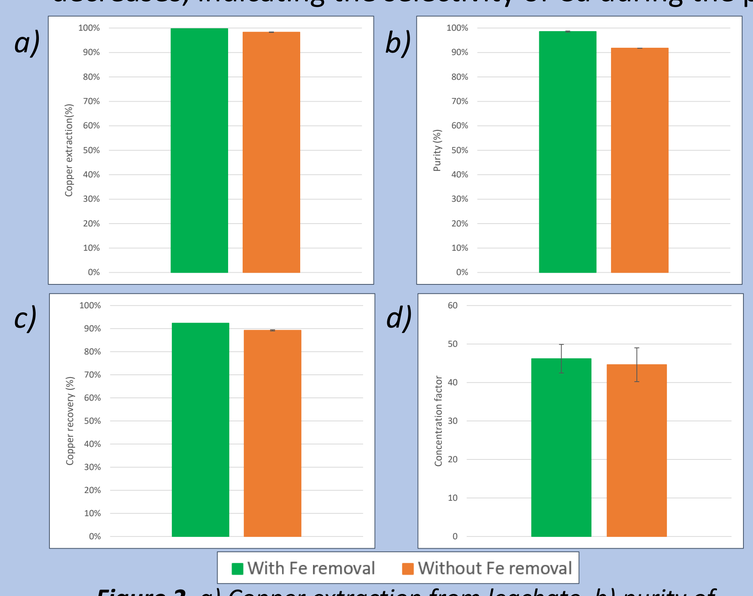


Figure 2. *a) Copper extraction from leachate, b) purity of deposited copper, c) copper recovery and d) concentration factor.*

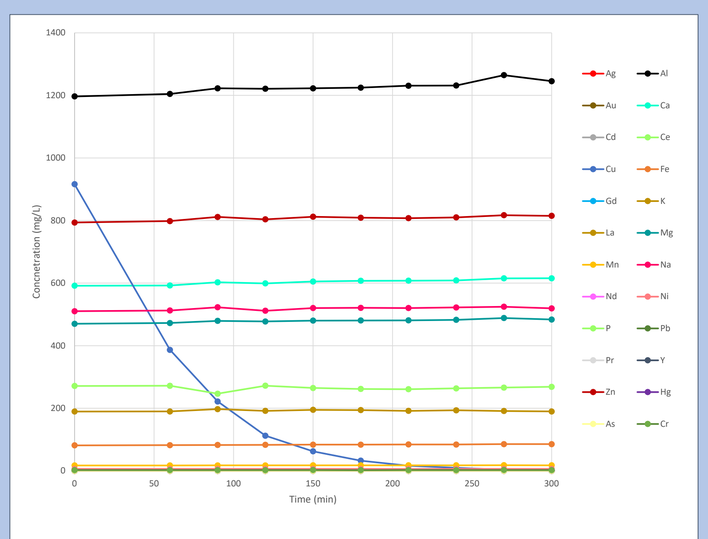


Figure 3. *Concentration evolution of the elements in the leachate without Fe.*

CONCLUSIONS

Experimental results shown that it was possible to extract more than 98% of copper from the leached stream by electrowinning process and to recover almost 90% in the cathodes, applying 200 A/m^2 during 5 h, when treating a sample with 1 g/L of Cu concentration at pH 1.5 in the leachate. By means of Fe precipitation process, using ammonia as the best reactive agent, these results were improved up to 99.7% of extraction and a recovery percentage of 92.4%.

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