

Parameters affecting Arsenic Recovery from Copper Smelting

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Abstract — The production of arsenic from the smelting of copper causes pollution, which has an adverse effect on human beings within the environment. Therefore, the objectives of this study were to investigate the solubility of arsenic in water and dilute sulphuric acid as well as to determine the optimum leaching conditions to recover arsenic. The leaching conditions used during the experimental work were as follows: the solid to liquid ratio of (1: 9), the leaching temperatures of (30°C, 50°C and 80°C), the residence time of (30 minutes, 1 hour and 2 hour), the sulphuric acid concentration of 0.2 mol /L, pH 2.5 and agitation speed of 350 – 400 rev/min. Under these conditions, the optimum leach conditions were found to be, leaching temperature 50°C, residence time 1 hour and pH 2.65 in acidic solution with a recovery of 57.76% arsenic. Arsenic was also found to be highly soluble in water with a maximum dissolution of 37.39 g/l. The recovery of arsenic from the dust by the hydrometallurgical route has proved to be effective.

Index Terms— Arsenic, Baghouse dust, Leaching, Smelting.

I. INTRODUCTION

DURING the production of copper in the ausmelt furnace, dust is normally captured in the baghouse as a means of air pollution control. The dust is generated as a result of gas cleaning process, containing condensate matter and fine particles semi-melted of concentrate, which are transported with the gas. This dust generally contains Cu, Fe, and other minor elements such as Pb, As, Cd, Sb, Zn and Bi. Due to the presence of arsenic in the dust, which is both toxic and carcinogenic, proper disposal at a hazardous waste site is required, hence increasing the cost of production. However, this cost could be reduced if arsenic can be removed from the dust through leaching.

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Arsenic is one of the most toxic element that can be found. Exposure to an arsenic-contaminated environment can cause adverse health effects, affecting the dermal, respiratory and cardiovascular systems as well as escalating mutagenic and carcinogenic hazards [1]. Environmental contamination by arsenic and its compound has thus raised considerable concern. The sources of arsenic resulting in environmental contamination are both natural and anthropogenic. The major activities that result in arsenic contamination are mining, smelting and converting operations of arsenic enriched metal ores in the metallurgical processes. These activities generate large quantities of arsenic-containing residuals, such as smelting slag and air-pollution control residual (dust) [2].

Despite the negative impacts of arsenic on humans and the environment, arsenic is widely used in the industrial production of wood preservatives, agricultural chemicals and in glass manufacturing industry [3-4]. Therefore, the recovery of arsenic from copper processing will serve as a raw material for these industries and also reduce environmental pollution.

Unfortunately, the arsenic content in copper ore is very high and it increases the cost of reducing the ore through pyrometallurgical processing route. Also there are some environmental issues associated with this route which makes the process not economically feasible. Therefore, a more cost effective and environmentally friendly process for removal of arsenic prior to pyrometallurgical processing of copper could be achieved by hydrometallurgical processing.

II. PROCEDURE

The dust samples captured in the baghouse of a copper smelter were used as starting materials in this study. Since the dust is already in powder form, no further attempt was made to change the particle size. The samples were first prepared by splitting in order to homogenize the material. Specific information including the chemical analysis is given in Table 1. The samples were leached in water and dilute sulphuric acid solutions.

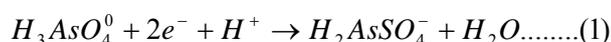
Table 1 Chemical composition of the baghouse dust

Element	As	Cu	Fe	Pb	Sb	Zn
Composition (%)	47.73	3.39	2.03	1.66	1.19	0.93

All leaching experiments were conducted in a 400 mL beaker containing demineralized water. The beaker was placed on a hot plate with a magnetic stirrer and allowed to

heat up to the required temperature. Sulphuric acid at a concentration of 19.6g/l was added to maintain a low pH during acid leaching. After the temperature was adjusted, solid feed dust was introduced into the beaker and the slurry was stirred continuously with a magnetic stirrer at 300 – 450 rpm. The slurry temperature was varied from 30°C to 80°C to evaluate effect of temperature and the leaching time was varied from 30 minutes to 2 hours. At the end each of experimental test, the solids were separated from solution by vacuum filtration. The volume of the pregnant solutions was recorded. The residue was dried at 105°C and its mass was recorded. The pregnant solution and residue were analyzed for their chemical compositions. The extraction of arsenic was calculated on the basis of the chemical composition of the residues.

The leaching mechanism of H_3AsO_4 to $H_2AsO_4^-$ in sulphuric acid solution can be represented by Reaction (1)



The dissociation of H_2SO_4 added as a leaching medium provides a hydrogen ion $[H^+]$ which maintains a low pH in the solution.

The pregnant solution and dust residue obtained after filtration were analyzed using the Inductively Coupled Plasma- Mass Spectrometer and Atomic Adsorption Spectroscopy techniques respectively to observe the change at the different leaching conditions.

III. RESULTS AND DISCUSSION

The effects of residence time on the leaching of arsenic was studied under the following conditions; the solid to liquid ratio (g/ml) of 1:9, the residence time of 30, 60 and 120 minutes, temperatures of 30°C, 50°C and 80°C, initial sulphuric acid concentration of 0.2 mole /L. The leach tests were conducted using water and sulphuric acid as lixiviant. The graphs were plotted using the average of the replication tests.

In this study, the results obtained during water and acid leaching are shown in Figure 1 and 2 respectively. Figures 1 and 2 illustrates that the extraction efficiency increases when the residence time is increased from 30 minutes to 60 minutes and decreases as the residence time is increased to 120 minutes. The increase in extraction efficiency indicates that most of the leaching occurs during the first 60 minutes of the reaction because at this time, the rate of dissolution is very fast increasing the concentration of arsenic in the solution. Increasing the residence time beyond 60 minutes may result in arsenic forming a protective layer which prevents the interaction between the lixiviant and arsenic molecules, therefore, resulting in the decrease in the rate of dissolution as can be seen in the graphs. A recovery of 59.08% was obtained in Figure 2 but it is not feasible to run a process for 30 minutes. Figure 3 shows the comparison between the extraction efficiencies obtained during acid and

water leaching, from the graph the appropriate residence time was selected to be 1 hour.

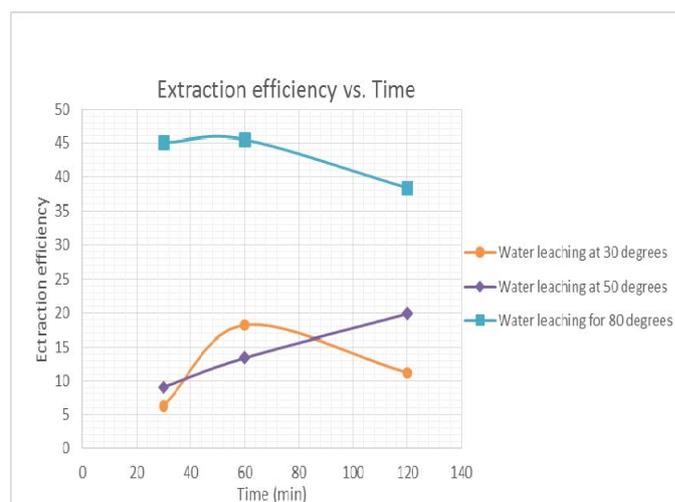


Figure 1: Effects of residence time on the extraction of arsenic during water leaching

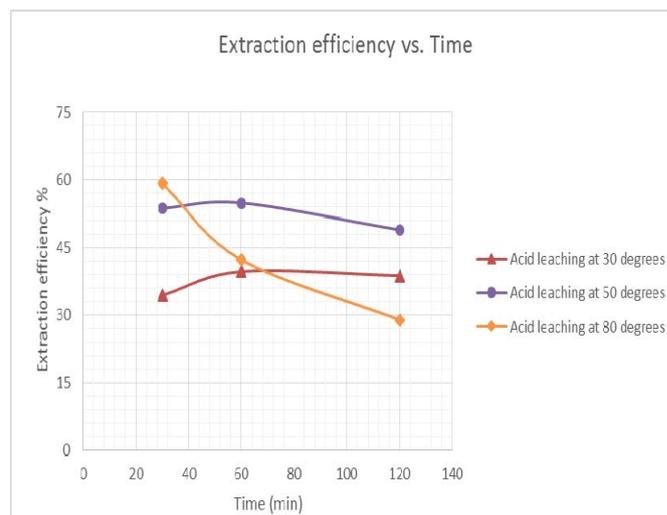


Figure 2: Effects of residence time on the extraction of arsenic during acid leaching

The effect of temperature on the extraction of arsenic is studied at 30°C, 50°C and 80°C. Figures 3 and 4 illustrates the effect of leaching temperature on the extraction of arsenic. Figure 3 shows that the extraction efficiency of arsenic increases with the increase of leaching temperature during water leaching. This is because as the temperature increases the reacting molecules gain more energy and collide faster, hence more collision increases the rate of dissolution. Graham *et al* [5], conducted an investigation into the leaching characteristics of baghouse dusts, although the tests were conducted at different pH values from the once used in the study, they found that increasing the temperature increases the extraction efficiency of arsenic in water.

In Figure 4 the extraction efficiency of arsenic increases when the temperature is raised from 30°C to 50°C during

acid leaching and decreases as the temperature is increased to 80°C. This shows that most of the leaching occurs at 50°C, at this temperature the particles are colliding faster increasing the rate of dissolution. Increasing the temperature to 80°C decreases the extraction efficiency of arsenic, this is due to the fact that, arsenic is usually co-precipitated into the residues with the precipitation of iron, which results in a significant decrease of the leaching of arsenic. Similar results were observed by Zhi-feng *et al* [6] when they conducted a study on the pressure leaching techniques of smelter dust with high-copper and high-arsenic.

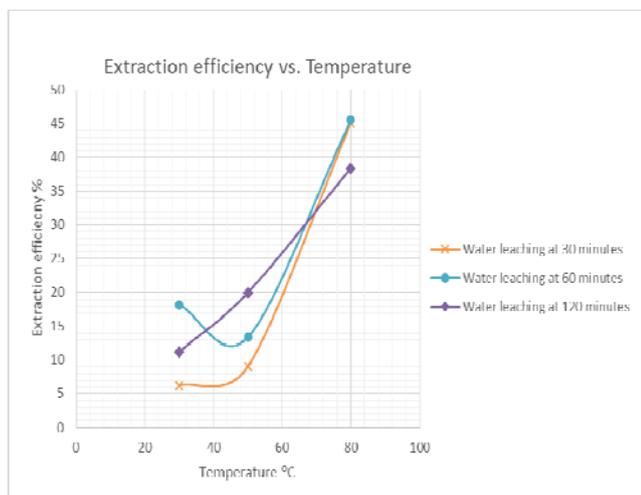


Figure 3: Effects of temperature on the extraction of arsenic during water leaching

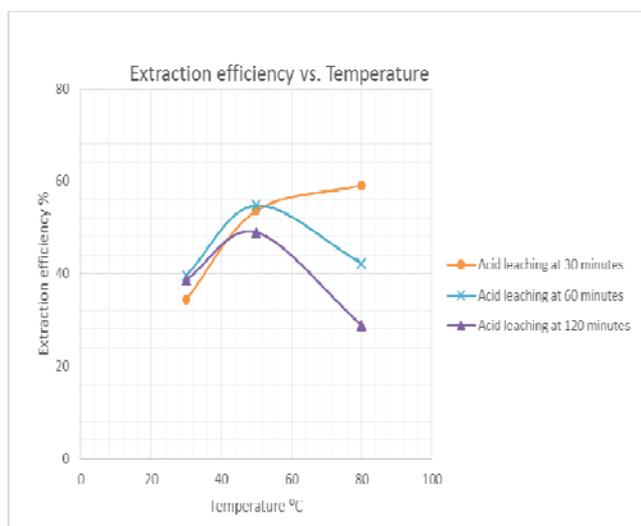


Figure 4: Effects of temperature on the extraction of arsenic during acid leaching

The effect of the initial sulphuric acid on the leaching of arsenic was studied. The experimental conditions are the same as those of temperature tests. The extraction of arsenic was as high as 54.76% when the initial sulphuric acid concentration was 0.2 mole/L. Zhi-feng *et al* [6] conducted a study on the pressure leaching techniques of smelter dust with high-copper and high-arsenic, they found that further increase of initial acidity can greatly increase the concentration of arsenic.

The dust was leached using water and dilute sulphuric acid as a leaching medium to investigate the dissolution of arsenic in the solutions. Figures 5 and 6 illustrate the effect of residence time on the dissolution of arsenic in water and acid filtrates. Figure 5 indicates that the concentration of arsenic in water increases slowly with an increase in residence time, the increase in extraction efficiency is due to the soluble amorphous or un-crystallized Arsenious oxide which is readily soluble in water [7]. In Figure 6 the dissolution of arsenic during acid leaching decreases as the residence time is increased from 30 to 60 minutes and increases when the time is increased to 120 minutes. This is because at 120 minutes the particles have more contact time with the lixiviant, hence the rate of dissolution increases and the solution is concentrated with arsenic.

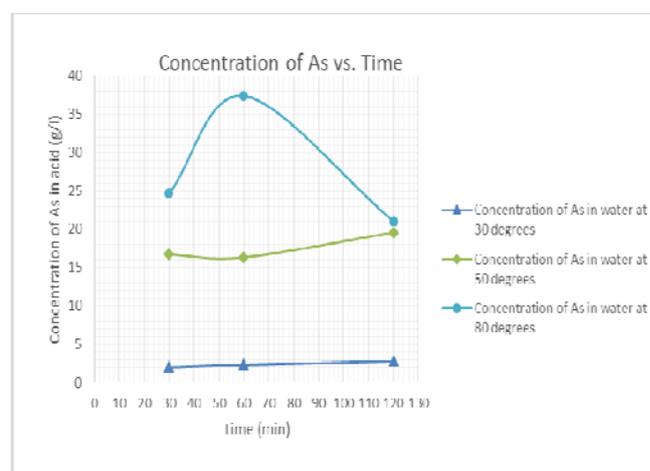


Figure 5: Effects of temperature on the dissolution of arsenic in water

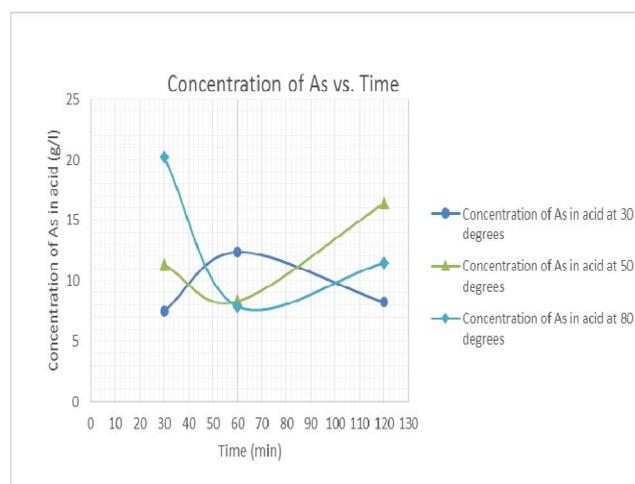


Figure 6: Effects of residence time on the dissolution of arsenic in acid

The Figures 7 and 8 illustrates the effect of temperature on the dissolution of arsenic in water and acid filtrates. Figure 7 shows that an increase in temperature, increases the concentration of arsenic in water. This shows that increasing the leaching temperature increases the rate of

reaction and the rate of dissolution, the effectiveness of the collision is important. In Figure 8 the concentration of arsenic decreases as the temperature is increased during acid leaching, this is because of the presence of iron which results in the co-precipitation of arsenic in the residue, hence decreasing the dissolution of arsenic into the solution [6].

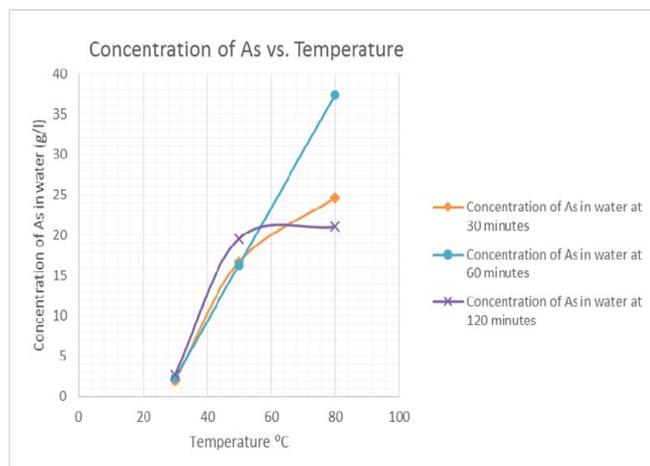


Figure 7: Effects of temperature on the dissolution of arsenic in water

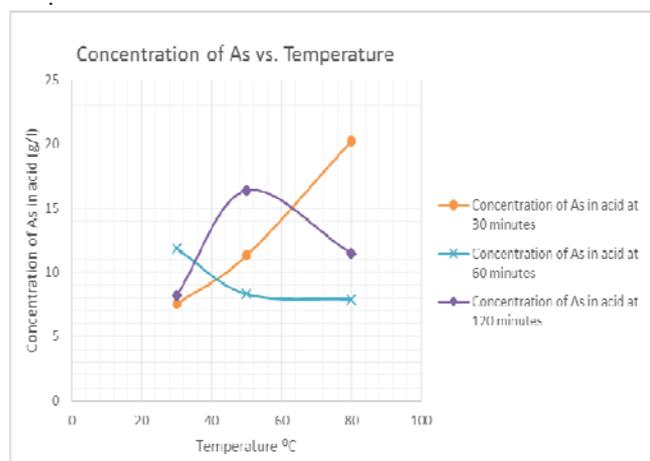


Figure 8: Effects of temperature on the dissolution of arsenic in acid

IV. CONCLUSION

From the leaching experiments, the following conditions were found to yield the optimum conditions: the solid to liquid ratio (g/mL) 9:1, the leaching temperature of 50°C, the residence time of 1 hour, the initial sulphuric acid concentration of 0.2 mol/L and agitation speed of 300-450 rpm. Under these conditions 54.76% of arsenic in the dust was leached. The recovery of arsenic from the dust by the hydrometallurgical route has proved to be effective.

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