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A STUDY ON HEAVY METALS MOBILITY FROM ZINC PLANT RESIDUES IN IRAN

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Abstract: The transport of heavy metals from mining disposal site to groundwater and surface water is one of the most serious environmental problems in the world. The transport of heavy metals such as Zn, Cd and Mn from leaching filter cake in RECo, Zanjan, Iran was examined by using column leaching. Parameters studied included: flow rate, pH of input solution and leaching time. In this study, the maximum dissolution percents of Zn, Cd and Mn in input solution pH of 5 were 45.50 %, 53.97% and 19.94%, respectively. To statistically analysis the experimental results, SPSS14 software was employed. The results of SPSS 14 indicated that for the Zn, Cd and Mn dissolution, time and flow rate were found respectively, the effective parameters for the pollution in zinc leach residues.

Keywords: *heavy metals, zinc leaching plant, leaching filter cake, column leaching*

Introduction

Metals are released into the environment at increasing rates by mining, industry, and agriculture, causing serious problems for environmental and human health (Li et al, 2000; Tang and Zhao, 2005).

Large areas of agricultural soils are contaminated by heavy metals that originate mainly from former or current mining activities, industrial emissions, or the application of sewage sludge. Elevated heavy metal concentrations in the soil can lead to enhanced crop uptake. Excessive metals in human nutrition can be toxic and can cause acute and chronic diseases (Geldmacher, 1984).

Cadmium and zinc for example, can lead to acute gastrointestinal and respiratory damage and acute heart, brain, and kidney damage (Friberg et al., 1986).

The production of non-ferrous metals from primary and secondary material results in the generation of a wide variety of wastes and residues. They are a result of the metals separation that is necessary for the production of pure metals from complex

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sources. These wastes and residues arise from the different stages of processing as well as from the off-gas and water treatment systems (Florijn and Van Beusichem, 1993; Hatch Associates Ltd., 2000; Ross, 1994; Wentz, 1989).

The transfer of heavy metals from soils to plants is dependent on three factors: the total amount of potentially available elements (quantity factor), the activity as well as the ionic ratios of elements in the soil solution (intensity factor), and the rate of element transfer from solid to liquid phases and to plant roots (reaction kinetics) (Brümmer et al., 1986).

A leach-electrolysis process for zinc production is practiced in zinc plant located in Zanjan, Iran. In that process a lot of filter cakes as by-product are generated daily. These wastes are retained for valuable elements recovery in the future and dumped in open stockpiles where they may cause heavy metal pollution problems. In these plants three types of wastes were produced: leaching filter cake, cobalt purification filter cake and Ni-Cd purification filter cake. All of the filter cakes have a high percent of heavy metal (Hakami, 2005).

In this study the metal releasing potential of zinc production by-products was investigated. The aim of this study is to discuss the leaching behavior of heavy metal in zinc plant residue (leaching filter cake) with special attention to the effects of input pH, input flow rate and leaching time on leachability of zinc, cadmium and manganese.

Materials and methods

Materials

Leaching filter cake for this study was obtained from Research & Engineering Co. for Non-ferrous Metals, Zanjan, Iran. After drying, the filter cake was ground and sieved to +200 mesh (74 μm). The chemical analysis was carried out by Perkin-Elmer AA300 model atomic absorption spectrophotometer. The analytic results were given in Table 1.

Table 1. Chemical analysis of leaching filter cake

Component	Zn	Pb	Fe	Mn	Co	Ni	Cd	Ca	Mg
Wt.%	7.55	8.13	2.35	0.14	0.02	0.02	0.09	7.67	0.27

Also XRD analysis of the sample was done and the results are shown in Fig. 1. Sulfuric acid was used to adjust the solution pH as required. Figure 2 demonstrates the process in which the leaching filter cake is produced.

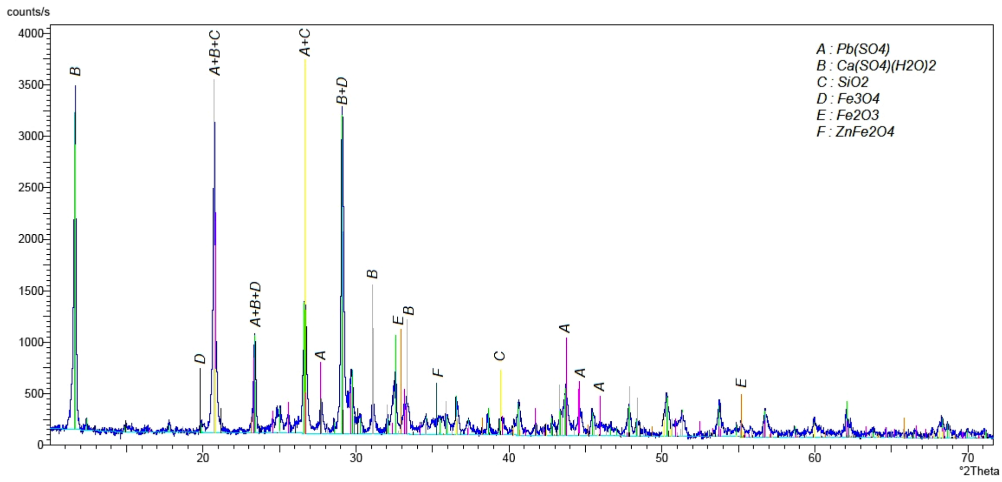

Fig. 1. X-ray diffraction analysis of the leaching filter cake used in the study

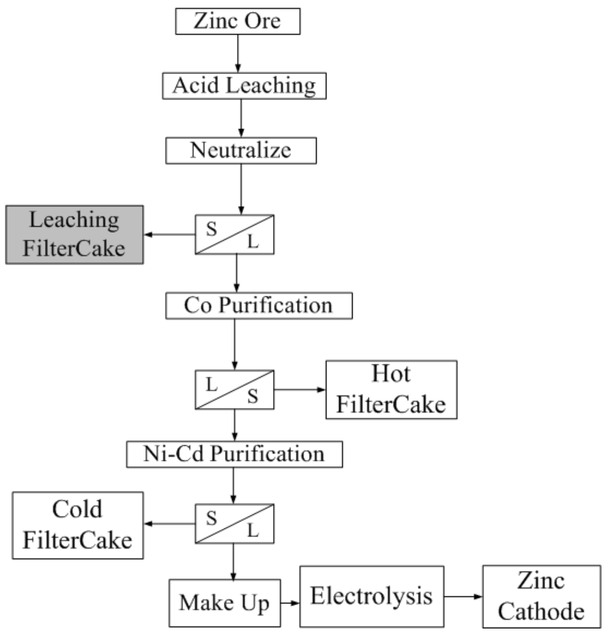

Fig. 2. Flow diagram of Filter Cake production in zinc plant used in this study

Experimental method

For experimental design and determining the important factors which affect the leachability of residual, the conventional method was used. In this study columns with 6 cm diameter and 50 cm length from Plexy glass were employed. A 2–4 cm layer of washed and dried sand with a Whatman paper was put at the end of each column.

About 875 g of dried leaching filter cake was placed. To attain uniform distribution of leaching solution a layer of fiber-glass between two Whatman papers were used in the top of each column. Process variables were pH of input solution, rate of input solution and leaching time. Table 2 shows the variation intervals for these parameters. Acid sparking time was 24 hours a day. During this time output solution was collected in a container to prepare reagent samples for measurements of Zn, Cd and Mn concentration after 2, 4, 6, 10, 15 and 20 days.

Table 2. Variation intervals of experimental parameter for the filter cake leaching

Parameter	Value					
Flow rate(cm^3/min)	0.5	1	2	–	–	–
Input pH	5	6	7	–	–	–
Leaching time (days)	2	4	6	10	15	20

Results and discussion

Effect of pH of input solution

The effect of input solution pH on the dissolution of Zn, Cd and Mn are shown in Figs 3, 5 and 7. Based on the pH of rain water in Zanjan city, three input solution pHs of 5, 6 and 7 were selected. The maximum dissolution of Zn, Cd and Mn was observed after two days with the input solution pH of 5 and the flow rate of 1 mm/min. They were equal to 26554.6 mg/dm^3, 365.5 mg/dm^3 and 232.7 mg/dm^3, respectively. The results shown in Figs 3, 5 and 7 indicate that the concentration of above mentioned metals decrease with increasing leaching time up to 20 days then reaches constant rate.

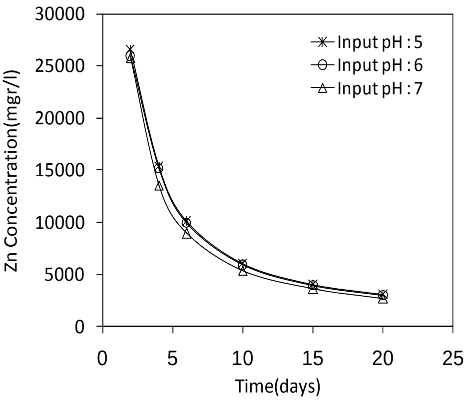

Fig. 3. Effect of input pH on the Zn dissolution

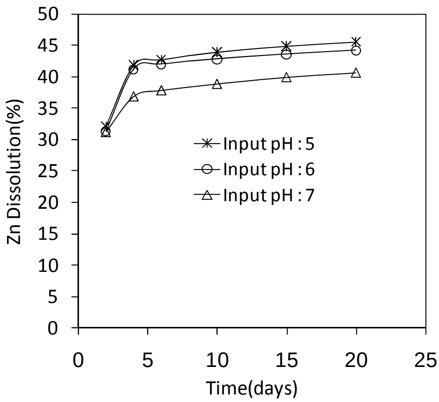

Fig. 4. Zn dissolution percentage at three different input pH

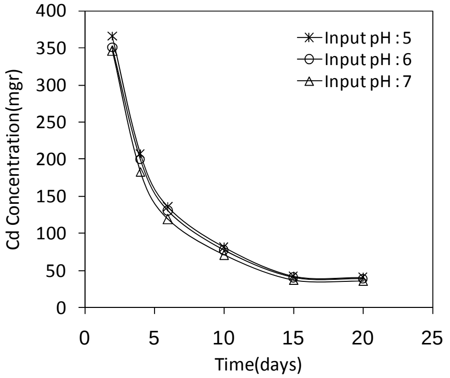

Fig. 5. Effect of input pH on the Cd dissolution

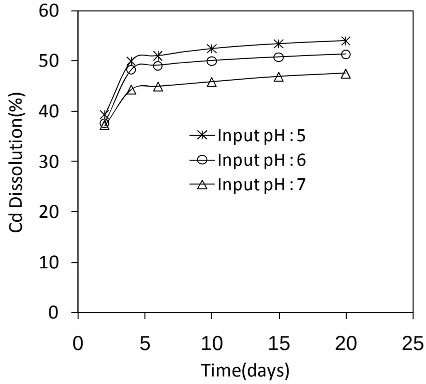

Fig. 6. Cd dissolution percentage at three different input pH

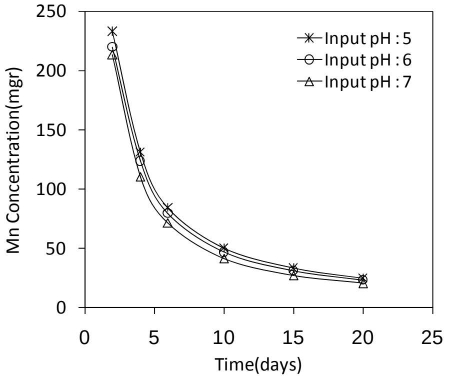

Fig. 7. Effect of input pH on the Mn dissolution

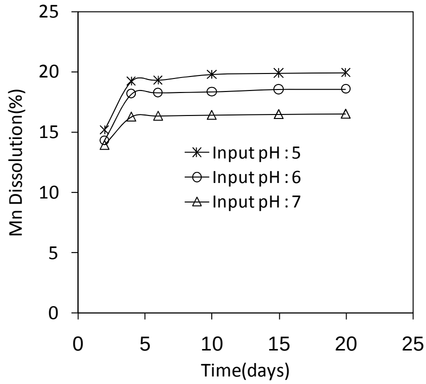

Fig. 8. Mn dissolution percentage at three different input pH

Figs 4, 6 and 8 show that the maximum dissolution percentages of Zn, Cd and Mn in input solution were attained at pH 5 and were 45.50%, 53.97% and 19.94%, respectively. The batch experiments showed that the dissolution percentage of Zn, Cd and Mn increased with increasing leaching time to 4 days, whereas the mentioned metals dissolution percentage did not change significantly with leaching time to 20 days.

Effect of input flow rate

Figures 9, 11 and 13 illustrate the effect of flow rate on the dissolution of Zn, Cd and Mn. Three flow rates of 0.5, 1 and 2 cm^3/min were selected. The maximum dissolution of Zn, Cd and Mn was achieved after two days with the flow rate of 0.5 ml/min and pH of 5 and amounted to 40527.3 mg/dm^3, 548.6 mg/dm^3 and 314.5 mg/dm^3, respectively.

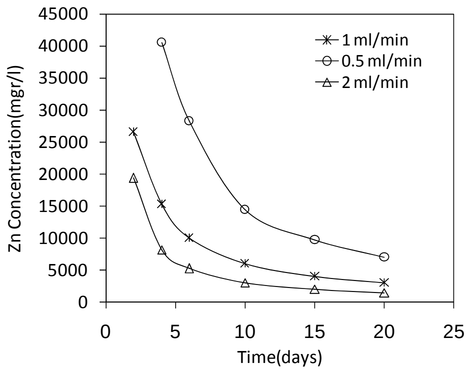

Fig. 9. Effect of flow rate on the Zn dissolution

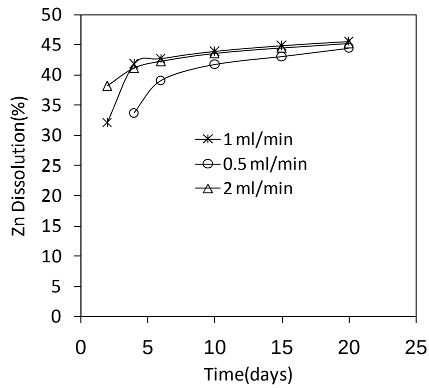

Fig. 10. Zn dissolution percentage at three different flow rates

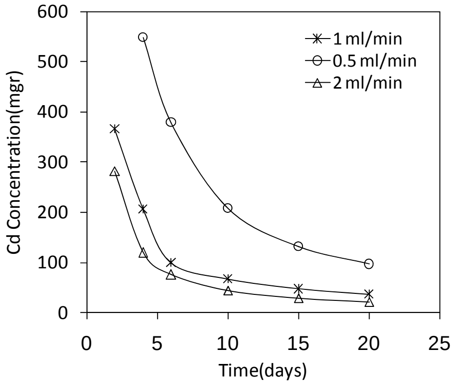

Fig. 11. Effect of flow rate on the Cd dissolution

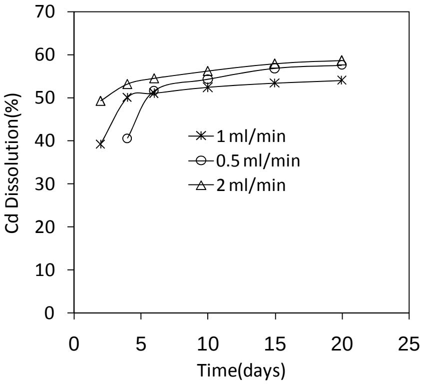

Fig.12. Cd dissolution percentage at three different flow rates

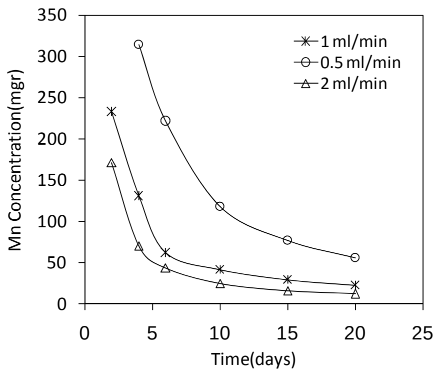

Fig. 13. Effect of flow rate on the Mn dissolution

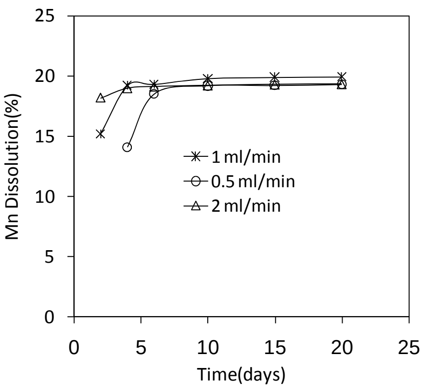

Fig. 14. Mn dissolution percentage at three different flow rates

As can be seen in Figs. 10,12 and14 the maximum dissolution percentages of Zn, Cd and Mn were attained at the flow rate of 1 ml/min and were 45.50%, 53.97% and 19.94%, respectively. As shown in those figures the results indicate that the dissolution percentages of above mentioned metals increase with increasing leaching time up to 4 days and then reaches a constant rate.

Experimental equation for estimation of dissolution percentage

The volume of solutions obtained from the columns in sampling days was determined. Zn, Cd and Mn content of each solution was measured. Basing on equation (1) the dissolution percentages of Zn, Cd and Mn were calculated

$$D = \frac{\text{volume of output solution} \times \text{element concentration}}{\text{weight of sample} \times \text{grade}} \times 100\,. \qquad (1)$$

The influence of flow rate, input pH and leaching time on the dissolution percentage was statistically analyzed by SPSS14 software using a multi-variable linear model. The relation between the dissolution percentages of elements and mentioned factors such as input pH, flow rate and leaching time was investigated.

The equation for dissolution percentage of zinc is given below:

$$D_{\mathrm{Zn}} = -0.053H + 0.266Q + 0.528t \qquad (2)$$

where H is input pH, Q is flow rate and t is leaching time.

For the dissolution percentage of cadmium the equation is:

$$D_{\mathrm{Cd}} = -0.151H + 0.318Q + 0.508t. \qquad (3)$$

The equation for dissolution percentage of manganese is:

$$D_{\mathrm{Mn}} = -0.163H + 0.268Q + 0.412t. \qquad (4)$$

As can be seen in the equations (2)–(4) the effective parameters governing transport of Zn, Cd and Mn to the environment are time and flow rate.

Conclusion

Experiments were carried out to investigate the effect of input pH, input flow rate and leaching time on the leaching behavior of heavy metals such as zinc, cadmium and manganese from zinc plant residue (leaching filter cake) to environment. A maximum dissolution of zinc, cadmium and manganese was obtained at following condition: flow rate of 1 ml/min, input pH 5 and leaching time 4 days. In this study, the most important parameters for dissolution of zinc, cadmium and manganese are time and flow rate, respectively, in range studied.

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