REMOVAL OF COPPER, ZINC AND NICKL FROM ACID MINE DRAINAGE BY NATURAL CLAY MINERALS: BATCH AND COLUMN STUDY

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ABSTRACT

Acid mine drainage (AMD) is created as a result of geochemical reaction occurring in mine. When sulfide minerals exposed in the atmosphere, they generated by the process of oxidation. The main characteristics of AMD are high acidity, high concentration of sulfate and contains wide range of heavy metal ions. This study was performed to remove the copper, zinc and nickel from AMD of copper mining at ambient temperature using both batch and column techniques. In batch technique was used from four natural clay minerals (bentonite, two type volcanic ash soil and red earth) in different dosage. However, in column technique we used from one natural clay mineral (volcanic ash soil). Results showed that the order capacity of adsorption by the 4 types of minerals is; bentonite>red earth>volcanic ash soils. Percentage of removal copper, zinc and nickel by bentonite at dose 60 g/l were 99.9%, 89.2% and 99.9%, respectively. Also, in all tests the pH of final solution increased and neutralization process is occurred.

Keywords: Removal, heavy metals, natural clay minerals, AMD

1. Introuduction

Acid mine drainage (AMD) is one of the major problem in present world, which is produced by the mining activities. AMD is created as a result of geochemical reaction; when sulfide minerals exposed in the atmosphere, they generated by the process of oxidation (Kalin *et al*., 2006; Ríos *et al*., 2008). The main characteristics of AMD are high acidity, high concentration of sulfate and contains wide range of heavy metal ions. If it is discharged into the environment without neutralization and removal of hazardous elements can have a serious adverse effect on vital resources. Therefore, acid mine drainage (ADM) can cause damage to human health (Mohan and Chander, 2006; Johnson *et al*., 2005; Cui *et al*., 2012; Kim and Kim, 2003; Măicăneanu *et a*l., 2013)

There are several methods for the treatment of acid mine drainage such as, chemical precipitation oxidation and hydrolysis, reverse osmosis, solvent extraction, ion exchange, neutralization, electrochemical remediation, adsorption and biosorption (Mohan and Chander, 2006; Feng *et al*., 2004; Tolonen et al., 2014). Absorption is a highly effective method for treating acidic mines drainage (ADM) (Motsi *et al*., 2009; Zhang, 2011). This due to the advantages of adsorption method such as efficient, simplicity of operation, access to the adsorbent materials, low cost, suitable for low concentrations, not require any chemical substances and little sludge production (Feng *et al.*, 2004)

This study was performed to remove the copper, zinc and nickel from AMD of copper mining by bentonite (Ben), two type volcanic ash soils (VAS-I, VAS- II and red earth (RE).

2. Materials and methods

This study was carried out at room temperature using both continuous and batch technique. The adsorbents were for this series of experiments were collected from Kerman province which is located in the south east part of Iran. In batch technique was used from four natural clay minerals (bentonite, two type volcanic ash soil and red earth) in different dosage. However, in column technique we used from one natural clay mineral (volcanic ash soil). First crushed using jaw crusher, then sieved and particle size less than -50 mesh were selected for tests. All chemical reagent used in this study were obtained from Merck with analytical grade. Acid mine drainage (AMD) collected from the Sarcheshmeh copper mine for testing. The chemical characteristics of acid drainage are shown in Table 1.

Table 1: The chemical characteristics of acid drainage

Composition	Concentration (mg/l)
Cu	80
Zn	13
Ni	1
pH	4.6
EC(mmhos/cm)	1795

In batch tests were used various amount adsorbents dosage (20, 30, 40 and 60 mg/l) and solutions volume (50 ml) mixed in 300 ml flat bottom Erlenmeyer flasks then was moved to rotary shaker and shaking for 300 min with speed 150 rpm. The suspensions were filtered using wathman filter paper and then metal ions concentration in filtrate was determined. Atomic absorption spectrometry (AAS) was used to measure the concentration of metals (Varian AA-975 and AA-1275 models).

In this study, the following conditions were constant in all experiments; temperature (27±1°C), particles size (-50 mesh), solutions volume (50 ml) and rate of shaking (150rpm).

The percent of metal ions removal by adsorbents was calculated by the following equation:

$$\%MS=\frac{C_O-C_e}{C_O}*100$$

Mass balance equation used to calculate the capacity of the adsorbents:

$$q_e=\frac{C_O-C_e}{m}*V$$

Where, q_e is amount of metal ions absorbed on adsorbents (mg/g); C_0 and C_e are the initial and equilibrium concentration (mg/L) of metal ions, respectively; V is the volume of AMD (L) and m is mass of adsorbent used (g).

The column studies were carried out by one adsorbent (volcanic ash soli). Column experiments were performed in a glass column with a height of 40 cm which was packed to a height of to 15 and 26 cm and internal diameter 2.5 and 1.5 cm. The tests were conducted in two flow rate (0.8 and 1.4 ml/min and particle size selected in range 10-20.

3. Results and discussion

Batch studies

With increasing amount of absorbents (bentonite, two type volcanic ash soil and red earth), increases removal of copper, nickel and zinc ions from acid mine drainage (AMD) (Fig.1 to 4). Also, the pH of the solutions increases with increasing amount of adsorbents. In addition to the removal of metal ions, neutralization process is occurred. Several investigators have confirmed these results (Sen and Gomez, 2006 ; Jiang *et al*., 2011; Mohan and Chander, 2006). Results showed that the order capacity of adsorption by the 4 types of minerals is; bentonite>red earth>volcanic ash soils.

Percentage of removal copper, zinc and nickel by bentonite at dose 60 g/l were 99.9%, 89.2% and 99.9%, respectively. The results showed that red earth and bentonite have high capability for removing of copper, zinc and nickel from AMD. The adsorption affinity order of the metal ions by all sorbents was Ni >Cu >Zn.

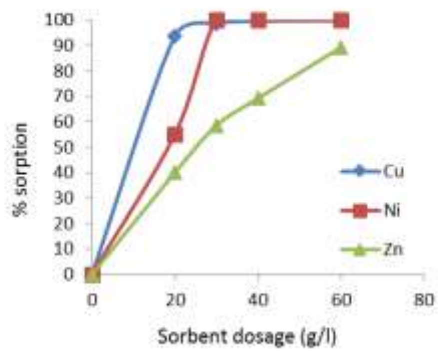

Figure1: Adsorption copper, nickl and zinc on Ben

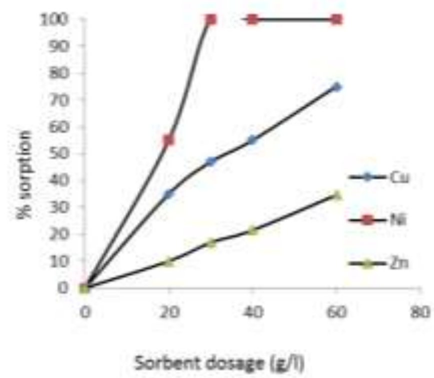

Figure 2: Adsorption copper, nickl and zinc on VAS-I

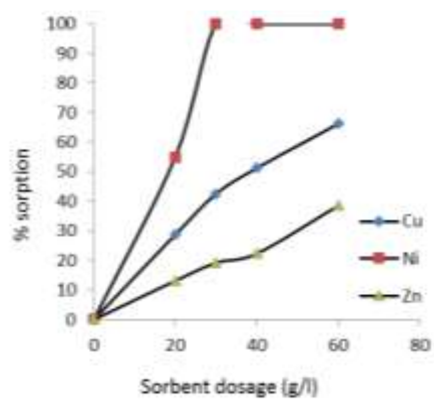

Figure 3: Adsorption copper, nickl and zinc on VAS-II

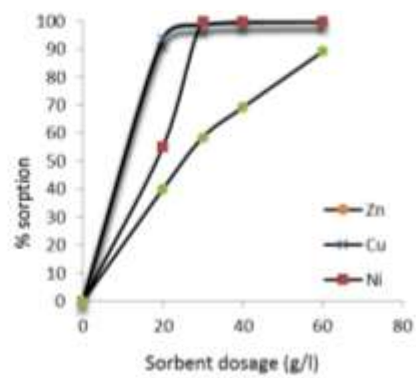

Figure 4: Adsorption copper, nickl and zinc on RE

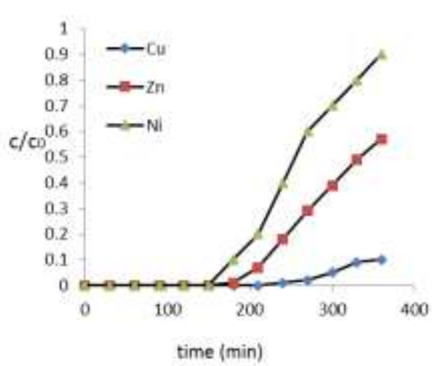

Figure 5: Breakthrough curve for the adsorption copper, nickl and zinc onto VAS-I (flow rate =0.8 ml/min ; T=27±1°C)

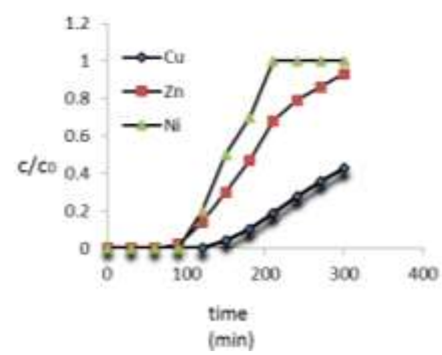

Figure 6: Breakthrough curve for the adsorption copper, nickl and zinc onto VAS-I (flow rate =1.4 ml/min ; T=27±1°C)

Column studies

In fixed-bed column studies adsorption data are described by using breakthrough curves (Atar *et al*. 2012). Figures 5 and 6 show the breakthrough curves for ions of copper, zinc and nickel. According to Figure 5, the critical concentration ($C/C_0 = 0.1$) of copper, zinc and nickel in the flow rate 0.8 ml/min is equal to 350, 160 and 170 min, respectively. In the flow rate 1.4 ml/min the critical concentration of copper, zinc and nickel was reduced and almost become to half the previous flow rate.

4. Conclutions

Results showed that the order capacity of adsorption by the 4 types of minerals is; bentonite>red earth>volcanic ash soils. Percentage of removal copper, zinc and nickel by bentonite at dose 60 g/l were 99.9%, 89.2% and 99.9%, respectively. Also, in all tests the pH of final solution increased and neutralization process is occurred.

REFERENCES

1. Atar N., Olgun A. and Wang S. (2012). Adsorption of cadmium (II) and zinc (II) on boron enrichment process waste in aqueous solutions: Batch and fixed-bed system studies, Chemical Engineering Journal, **192**, 1-7.
2. Cui M., Jang M., Cho SH., Khim J. and Cannon FS. (2012). A continuous pilot-scale system using coal-mine drainage sludge to treat acid mine drainage contaminated with high concentrations of Pb, Zn, and other heavy metals, J Hazard Mater., **215-216**, 122-8.
3. Feng D., van Deventer J.S.J. and Aldrich C. (2004). Removal of pollutants from acid mine wastewater using metallurgical by-product slags, Separation and Purification Technology, **40**, 61-67.
4. Jiang K., Sun T., Sun L. and Li H., (2006). Adsorption characteristics of copper, lead, zinc and cadmium ions by tourmaline. J. Environ. Sci. **18**, 1221-1225.
5. Johnson DB. and Hallberg K. B. (2005). Acid mine drainage remediation options: a review, Sci Total Environ. **338**, 3–14.
6. Kalin M, Fyson A. and Wheeler WN. (2006). The chemistry of conventional and alternative treatment systems for the neutralization of acid mine drainage, Sci Total Environ., **366**, 395-408.
7. Kim JJ. and Kim SJ. (2004). Seasonal factors controlling mineral precipitation in the acid mine drainage at Donghae coal mine, Korea, Sci Total Environ., **325**, 181-91.
8. Măicăneanu A., Bedelean H., Ardelean M., Burcă S. and Stanca M. (2013). Haneş and Valea Vinului (Romania) closed mines Acid Mine Drainages (AMDs) – Actual condition and passive treatment remediation proposal, Chemosphere, **93**, 1400-1405. Mohan D. and Chander S. (2006). Removal and recovery of metal ions from acid mine drainage using lignite--A low cost sorbent, J Hazard Mater., 137, 1545-53.
9. Motsi T., Rowson N.A. and Simmons M.J.H. (2009). Adsorption of heavy metals from acid mine drainage by natural zeolite, International Journal of Mineral Processing, **92**, 42-48.
10. Ríos CA., Williams CD. and Roberts CL. (2008). Removal of heavy metals from acid mine drainage (AMD) using coal fly ash, natural clinker and synthetic zeolites, J Hazard Mater., **156**, 23-35.
11. Sen T.K. and Gomez D., (2011). Adsorption of zinc (Zn^{2+}) from aqueous solution on natural bentonite. Desalination 2**67**, 286-294.
12. Tolonen E-T., Sarpola A., Hu T. Rämö J. and Lassi U. (2014). Acid mine drainage treatment using by-products from quicklime manufacturing as neutralization chemicals, Chemosphere, **117**, 419-424.
13. Zhang M. (2011). Adsorption study of Pb(II), Cu(II) and Zn(II) from simulated acid mine drainage using dairy manure compost, Chemical Engineering Journal, **172**, 361-368.