The Cadmium Adsorption Study by Using Seyitomer Fly Ash, Diatomite and Molasses in Wastewater

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Abstract—Fly ash is an important waste, produced in thermal power plants which causes very important environmental pollutions. For this reason the usage and evaluation of the fly ash in various areas are very important. Nearly, 15 million tons/year of fly ash is produced in Turkey. In this study, usage of fly ash with diatomite and molasses for heavy metal (Cd) adsorption from wastewater is investigated. The samples of Seyitomer region fly ash were analyzed by X-ray fluorescence (XRF) and Scanning Electron Microscope (SEM) then diatomite (0 and 1% in terms of fly ash, w/w) and molasses (0-0.75 mL) were pelletized under 30 MPa of pressure for the usage of cadmium (Cd) adsorption in wastewater. After the adsorption process, samples of Seyitomer were analyzed using Optical Emission Spectroscopy (ICP-OES). As a result, it is seen that the usage of Seyitomer fly ash is proper for cadmium (Cd) adsorption and an optimum adsorption yield with 52% is found at a compound with Seyitomer fly ash (10 g), diatomite (0.5 g) and molasses (0.75 mL) at 2.5 h of reaction time, pH:4, 20ºC of reaction temperature and 300 rpm of stirring rate.

Keywords—Heavy metal, fly ash, molasses, diatomite, adsorption, wastewater.

I. INTRODUCTION

Heavy metals are one of the most important contaminants in water and soil which are discharged to the environment by several industries, such as mining, metallurgical, electronic, electroplating and metal finishing.

The removal of heavy metals from wastewater is of critical importance due to their high toxicity and tendency to accumulate in living organisms. Moreover, heavy metals cannot be degraded or destroyed [1]. In recent years, heavy metal pollution has become one of the most serious environmental problems. The major toxic metal ions hazardous to humans as well as other forms of life are Cr, Fe, Cu, Co, Ni, Cd, Hg, As, Pb and Zn etc… [2].

Adsorption is preferred for the removal of these pollutants due to easy handling and removal performance. On the other hand, the economy and efficiency of the adsorption process are limited by the physicochemical characteristics and the cost of the adsorbent. In this context, several works have reported the adsorption of dyes and heavy metals in mono-component solutions using low-cost adsorbents of inorganic origin such as: clays [3], egg shell [4], fly ash [5], sandstone [6], rice husk ash [7], zeolites [8], shells of lentil, wheat and rice [9] among others.

Fly ash is the by-product of thermal power stations and is a waste material available in large quantities free of cost. Chemical and physical properties of fly ash differ according to the nature of the coal used in thermal power stations. Heavy metals like Zn, Pb, Cd, Ni and Cu have been removed from municipal solid waste leachate by fly ash [10] of thermal power plant.

Diatomite, also known as diatomaceous earth or kieselguhr, is a fine sedimentary rock of biogenetic origin, which mainly consists of amorphous hydrous silica (SiO$_2$·nH$_2$O) that derives from the skeletons of aquatic plants called diatoms. In addition to bound water, varying between 3.5 and 8.0%, the siliceous skeleton may also contain, in solid solution or as part of the SiO$_2$ complex, small amounts of associated inorganic components – alumina, principally – and lesser amounts of iron, alkaline earth, alkali metals and other minor constituents [11].

Molasses, 23% of the hemicellulose formed by nitrogen-free organic nitrogenous substances with pectin, 12% of potassium, sodium, iron minerals such as organic matter composition, constitute 15% of water. pH is between 5.5 and 10 [12].

The purpose of this study is to investigate the possibility of the usage of Seyitomer fly ash as low-cost adsorbents for cadmium adsorption. Differently from the literature, molasses which is a waste of sugar production process is evaluated with Seyitomer fly ash.

Seyitomer fly ash was characterized by using XRF and SEM techniques, to determine the chemical composition and morphology. It was seen that adsorption yield (in percent) was affected by amounts of diatomite (in percent) and molasses (in milliliter).

II. EXPERIMENTAL

A. Raw Materials

The Seyitomer fly ash (Fig. 1 (a)), diatomite (Fig. 1 (b)) and molasses (Fig. 1 (c)) were supplied by Areas Cement Construction Incorporated Company, Kutahya Cement Factory, Konya sugar refinery, respectively.
III. Results and Discussion

A. Characterization of the Raw Materials

Seyitomer fly ash was generally heterogeneous, consisting of a various identifiable crystalline phases such as quartz (SiO₂), iron oxide (Fe₂O₃) and aluminum oxide (Al₂O₃). The total amount of SiO₂, Al₂O₃, Fe₂O₃ Seyitomer fly ash exceeded 70% as previous study [14]. The iron (Fe₂O₃) content was found higher in Seyitomer fly ash. Then distribution of the compounds of Seyitomer fly ash used in this study is shown in Fig. 4. The SiO₂ and aluminum oxide (Al₂O₃) contents were 52 and 18%, respectively.

The chemical analysis of diatomite was shown in Fig. 5. The main component of diatomite is SiO₂, with a relatively small percentage of other oxides such as Al₂O₃, Fe₂O₃, MgO and others.

Particle sizes of Seyitomer fly ash (Fig. 6 (a)) and diatomite (Fig. 6 (b)) were found between 2-10 µm and 4-37 µm, respectively under the SEM.
B. Methods and Characterizations

A series of pelletization experiments were conducted to show the effect of diatomite (in percent) and molasses (in milliliters) addition on the formation of fly ash pellets. The ratio of diatomite was used between 0-1%. The amount of molasses was selected between 0-0.75 mL (50% of molasses + 50% of distilled water). The pelletization results showed that molasses was a fundamental binder for Seyitomer fly ash. Pellets were fragile when molasses was not used.

C. Adsorption Experiments

Adsorption process was conducted between 30-180 minutes. Then samples were analyzed by ICP-OES instrument and results were shown in Table I.

The pelleting conditions were determined in terms of adsorption yield (in percent) as 10 g of Seyitomer fly ash, 0.5% of diatomite and 0.75 mL of molasses and the maximum adsorption yield was found 52% for 150 min. Optimum adsorption results were shown in at Fig. 7.

IV. CONCLUSIONS

In this study, Seyitomer fly ash, diatomite and molasses were pelletized under determined conditions for Cd$^{2+}$ adsorption where they are the wastes that can easily be found in Turkey. Characterization results showed that the SiO$_2$ and Al$_2$O$_3$ contents for Seyitomer fly ash were 52 and 18%, respectively.

Optimum adsorption yields of Cd$^{2+}$ was found as 3, 5, 47, 33, 33, 33 (%) at 30, 60, 90, 120, 150, 180 minutes. Seyitomer fly ash was proper for Cd$^{2+}$ adsorption and an optimum adsorption yield with 52% was found at a compound with Seyitomer fly ash (10 g), diatomite (0.5 g) and molasses (0.75 mL) at 2.5 h of reaction time, pH:4, 20ºC of reaction temperature and 300 rpm of stirring rate.

From the results of this study, it was seen that molasses and diatomite can be evaluated with fly ash.

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REFERENCES

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