International Journal of Chemical, Materials and Biomolecular Sciences
ISSN: 2415-6620
Vol:8, No:10, 2014

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 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, Se, V, 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 awaste 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. Heavymetals 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 ($SiO_2{\cdot}nH_2O$) 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.

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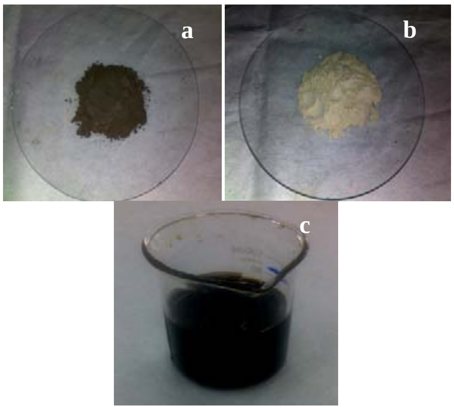

Fig. 1 Raw materials: (a) Seyitomer fly ash (b) Diatomite (c) Molasses

B. Methods and Characterizations

Seyitomer fly ash dried at 105ºC for 24 h, then they were analyzed by using XRF (Panalytical-Minipal4) and SEM (Cam Scan- Apollo 300), respectively (Figs. 2, 3). SEM is one of the best and most widely used techniques for the chemical and physical characterization of fly ash [13]. Then, fly ash, diatomite (0 and 1% in terms of fly ash, w/w) and molasses (0, 0.25, 0.50 and 0.75 mL) were pelletized by Manfredi OL57 pellet machine with 4 cm diameter of pellets and under 30 MPa of pressure, where diatomite was used as a binder in the pelletization process for Seyitomer fly ash. Pellets were dried at 105ºC for 24 h. Subsequently, the pellets were sintered in a high-temperature at 1200ºC.

Five hundred parts per million of synthetic wastewater (5 ppm Cd solution) were prepared with a magnetic stirrer for 2 h prepared at 500 rpm of stirring rate and 20ºC of temperature.

Fig. 2 Panalytical-Minipal4 XRF

Pellets were used at 20ºC of reaction time, 300 rpm of stirring rate and 3 h of reaction time for Cd heavy metal adsorption. The effects of diatomite (in percent) and molasses (in milliliter) on adsorption yield were examined.

Fig. 3 Cam Scan- Apollo 300 SEM

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 (SiO_2), iron oxide (Al_2O_3) and aluminum oxide (Fe_2O_3). The total amount of SiO_2, Al_2O_3, Fe_2O_3 Seyitomer fly ash exceeded 70% as previous study [14]. The iron (Fe_2O_3) 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 SiO_2 and aluminum oxide (Al_2O_3) contents were 52 and 18%, respectively.

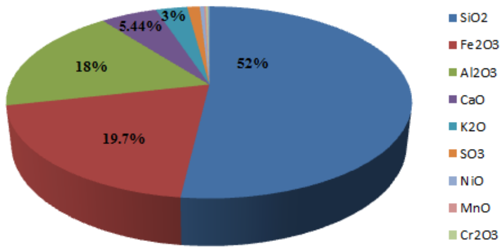

Fig. 4 Chemical compositions of the Seyitomer fly ash

The chemical analysis of diatomite was shown in Fig. 5.The main component of diatomite is SiO_2, with a relatively small percentage of other oxides such as Al_2O_3, Fe_2O_3, MgO and others.

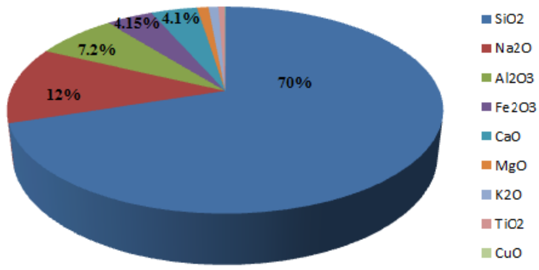

Fig. 5 Chemical compositions of the diatomite

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.

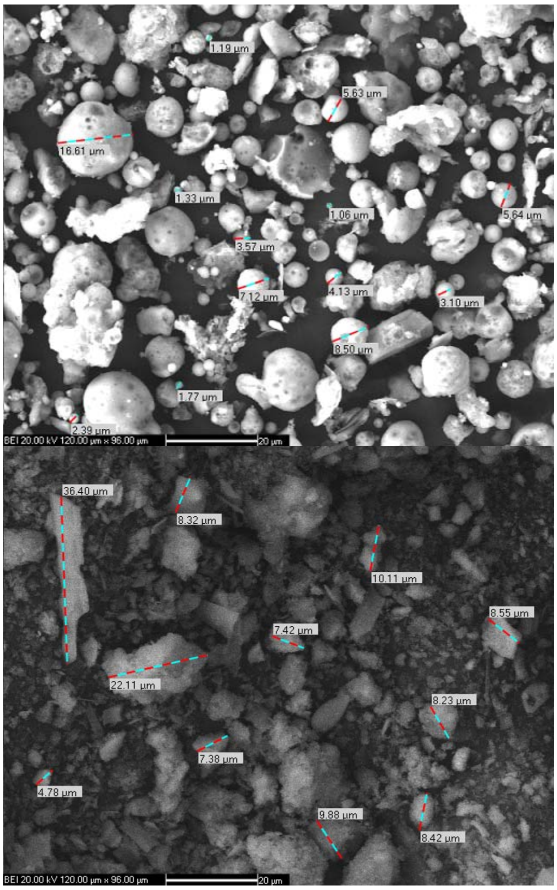

Fig. 6 SEM images: (a)Seyitomer fly ash (×1000 magnification) (b) Diatomite (×1000 magnification)

B. Methods and Characterizations

A series of pelletization experiments were conducted to show the effect of diatomite (in percent) and molasses (in milliliter) 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 between30-180 minutes. Then samples were analyzed by ICP-OES instrument and results were shown in Table I.

The pelletization 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.

TABLE I
THE ICP-OES RESULTS FOR Cd^{+2}ADSORPTION OF SEYITOMER FLY ASH (10 G) (20ºC, 300 RPM, PH:4)

Diatomite (in terms of fly ash, w/w) (%)	Molasses (mL)	Formation of pellet	Adsorption yield (%)					
			30	60	90	120	150	180
			min					
0.5	0	-	-	-	-	-	-	-
0.5	0.25	+	38	37	44	33	33	33
0.5	0.50	+	3	5	47	33	33	33
0.5	0.75	+	5	2	-	45	52	47
1	0	-	-	-	-	-	-	-
1	0.25	+	-	-	-	-	-	-
1	0.50	+	-	-	-	-	-	-
1	0.75	+	-	-	-	-	-	-

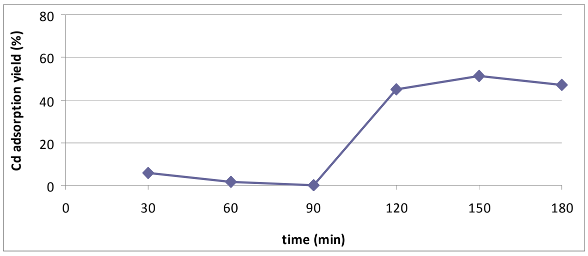

Fig. 7 Cd^{+2} adsorption yield depending upon time for optimum conditions by using Seyitomer fly ash (with diatomite and molasses)

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_2O_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 adsoption 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 as and diatomite can be evaluated with fly ash.

ACKNOWLEDGMENT

This research has been supported by Yıldız Technical University Scientific Research Projects Coordination Department. Project Number:YTU-2011-07-01-KAP01.

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