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Natural diatomite as an effective adsorbent for heavy metals in water and wastewater treatment (a batch study)

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Abstract

This study presents an evaluation of Egyptian diatomite as a low cost adsorbent for the removal of heavy metal under different conditions (pH, weight of diatomite and contact time). The adsorption of heavy metals was investigated under various pH values ranged from 2 to 8 at 25 °C. The obtained results indicate that at low pH (2–4), the removal efficiency of diatomite for heavy metal increased slightly as the pH, adsorbent dose and contact time increased, while at pH > 4, the percentage of metal ions adsorbed decreased with increasing pH due to precipitation of heavy metals. At pH equal 4, with using 2 g L^{-1} of diatomite and 75 min as contact time, the maximum adsorption capacity of diatomite was obtained. The high adsorption capacity of diatomite makes it a suitable low cost material for the removal of different heavy metals from aqueous solutions.

Keywords: Diatomite clay; Heavy metals treatment; Adsorption; Removal efficiency

1. Introduction

The removal of heavy metals ions from the environment is a big concern due to their association with health hazards for all living organisms due to its toxicity and non-biodegradable nature (El-Bayaa et al., 2009; Xue et al., 2009). The municipal and industrial solid wastes are another important source of pollution, which are considered a main source of the heavy metals like Hg, Cd, Fe, Mn, Pb and the treatment of these wastes must be agreed with the environmental standard before it is reused or returned to surface water (Ali and El-Sayed, 2017). There are many techniques have been developed such as chemical precipitation, reverse osmosis, ion exchange, and adsorption to remove heavy metals and other hazard materials from wastewaters (Shi et al., 2009). Among all of the previous techniques, the adsorption on

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clay and other chemical substances is considered to be a particularly more effective process specially by using low cost and environment friendly martial for the removal of heavy metals from industrial wastewaters and aqueous solutions (Lin and Juang, 2002; Swayampakula et al., 2009).

The most common sorption methods are using of natural clay minerals and activated carbon which has high metal adsorption capacity (Ayala et al., 2008). Although activated carbon is effective in the removal of metal ions from wastewater, it is expensive and requires chelating agents to enhance its performance, thus increasing treatment cost (Oliveira et al., 2005). Some researchers have focused on using low cost, highly efficient sorbents for pollutants, and the sorption behavior of several natural materials and chemical products has also been studied (Ijagbemi et al., 2009). Some of these materials are clay minerals (Solener et al., 2008), agricultural bi-products, some aquatic plants, and microorganisms (Ijagbemi et al., 2009). Most of these investigations have shown that natural materials can act as good sorbents for hazard materials including heavy metals (Ali and El-Sayed, 2017), while the types and availability of clay minerals also are important, because they are involved in choosing which pollutants will be treated. Egypt has huge reserves of diatomite deposits in Gebel Elow El Masakheet at south west El-Fayoum Governorate. These deposits vary in the quality grade from high, moderate to low (Ibrahim and Selim, 2011). The diatomite deposits of the El-Fayoum area are fine and regular in lamination developed through seasonal fluctuation of sedimentation. The deposits are overlain in some parts by detrital materials such as blown sands and semi-consolidated sandy clay. Because diatomaceous deposits occur in the form of several disconnected outcrops extending over about 30 km from Qasr Elsagha to Kom Oshim in the east, some authors concluded that they were formed in separate lakes.

Diatomite is a siliceous sedimentary rock composed of an amorphous form of silica ($SiO_2 \cdot nH_2O$) containing a small amount of microcrystalline material. It has a unique combination of physical and chemical properties such as high porosity, high permeability, small particle size, large surface area, and low thermal conductivity. Due to these properties the diatomite has been successfully used for cleaning drinking water or industrial and sewage waste water. Sometimes it is blended with aluminum chloride or ferric chloride to enhance the filtration processes (Marquez et al., 2004; Qdais and Moussa, 2004).

The removal of hazardous contaminants from wastewater using natural zeolite was performed by Ali et al. (2017). Their results indicate that, the uptake of clinoptilolite for ammonium was ranged from 70 to 92%, while it ranged from 70 to 99% for heavy metals at various conditions. The removal efficiency of zinc from aqueous solution with different adsorbents was investigated by Bhattacharya et al. (2006), the obtained results showed that the adsorption percentage of zinc increased by increasing the concentration of the adsorbents to reach maximum uptake at 98% and pH between 5 and 7.

This study aims to investigate and evaluate the removal capacities of diatomite for some metal ions such as aluminum (Al^{+3}), barium (Ba^{+2}), cadmium (Cd^{+2}), chromium (Cr^{+3}), copper (Cu^{+2}), iron (Fe^{+2}), lead (Pd^{+2}), manganese (Mn^{+2}), nickel (Ni^{+2}), and zinc (Zn^{+2}). The adsorption experiments were performed in laboratory, using metal ions initial concentration, pH of solution, and contact time as variables.

2. Materials and methods

2.1. Identification of clay

Diatomite sample was obtained by the Egyptian Mineral Resources Authority from Kom Oshim in the east of El-Fayoum Governorate (Fig. 1). The diatomite sample was crushed using roller mills and the small sizes were selected to be prepared for the batch study, while the large size was used for physical and chemical identification. The characterizations of diatomite were performed using X-ray (model X Pert PRO). All the previous analysis were done including electroscaning microscope (ESM) at the Laboratories of The Egyptian Mineral Resources Authority.

2.2. Diatomite preparation for the study

A representative sample of diatomite was prepared for the batch experiment by washing with distilled water to remove any non-adhesive impurities and then, dried in oven at 80 °C for 24 h to remove any moisture. The diatomite sample was grinded to 0.25–0.5 mm size to be used for the batch study (Reddy and Dastgheibi, 2014).

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