Removal of heavy metals (lead, cadmium, zinc, nickel and iron) from water by bio-ceramic absorbers of hydroxy-apatite microparticles

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ABSTRACT: Heavy metals are highly poisonous in the environment, even in small quantities, and endanger certain species and all live beings. Current methods of removing heavy metals from aqueous media include chemical sequestration, ion exchange, surface absorption, membrane processes, oxidation and revival procedures which have high investment and exploitation costs. Hence, it is significantly necessary to develop new and economical methods for effective removal of these metals from water and sewage. The present paper aims to evaluate efficiency of microparticles in removing heavy metals from water. Results of application of hydroxy-apatite microparticles as absorbers of heavy metals show that the absorption percentage average of lead (84.72%) by hydroxy-apatite microparticles is greater than that of cadmium (49.89%), zinc (72.90%), iron (74.50%) and nickel (79.25%).

Keywords: *Water filtration; heavy metals; hydroxy-apatite microparticles; atomic absorption*

INTRODUCTION

Environmental pollution with poisonous and dangerous heavy metals is a main concern in modern societies (Chong *et al.,* 2000; Liehr *et al.,* 1994; Matheical and Yu, 1996). These metals are naturally present in different layers of the earth and human interfaces including urban, industrial and agricultural sewage, mine discovery and exploitation, fossil fuel consumption, etc. increase their accumulation in the environment(Fergusson, 1990). Sewage of industries, such as mine, weaving, leather, tanning, electroplating using zinc, galvanizing dyeing material, metal extraction and fusion (Ahluwalia and Goyal, 2007), manufacturing electrical equipments, alloys, battery, insecticides, sludge resulted from sewage filtration, the ash produced from burning trash and garbage, and radioactive processes, contain significant amounts of ions of poisonous metals (Ahluwalia and Goyal, 2007). Heavy metals such as zinc, lead and chrome have various applications in basic engineering tasks including paper production, leather tanning, organic chemicals and oil chemical-based fertilizers. Ions of heavy metals have potentially endanger human health and lead to physical harms and even threatening diseases such as irreversible harm to body's vital systems (Malik, 2004). By developing several mechanisms these

metals remove the balance in live beings, especially humans, and result in a wide range of consequences and disorders (Chong *et al.,* 2000). The most important of these consequences include carcinogenicity, effects on central and peripheral nervous system, skin diseases, blood disorders, cardiovascular diseases, kidney harm and mass accumulation in tissues. Most effects of such metals on human health are not known yet. Metal ions accumulate in the environment and enter food chains (Volesky and Schiewer, 2000). Therefore, removal of heavy metals from aqueous environment is a significant public health issue in two aspects (McEldowney and Hardman, 1993; Eckenfelder, 1993) removal of heavy metals from industrial wastewater, agricultural drained water, mines and neutralizing their poisonous effects, and 2) revive and recover metals which is a necessary task considering the gradual reduction of mineral resources.

There are several methods to remove heavy metals from the environment which mainly involve physical, chemical and biological ways (Zhang *et al.,* 2007). Current physical methods include normal and membrane filtration (nano-filtration), reverse osmosis, surface absorption in stable and floating beds, coagulation – flocculation and flotation (Kurniawan *et al.,* 2006). Among chemical methods are sequestrate neutralization using soda, lime or

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sodium carbonate. Several models are also presented in the field of biological methods but constraints such as complexity of separation process, creation of secondary pollutions and imposing high costs limits the development of such methods (Kim *et al.,* 2006). Calcium hydroxy-apatite (HAP) [$Ca_{10}(PO_4)_6(OH)_2$] is used to remove poisonous elements from polluted soils and sewage (Omar and Al-Itawi, 2007; Takeuchi and Arai, 2007). It is a part of a rough tissue and has various applications in industry and medicine. Its artificial particles are employed as biceramics, chromatographic absorber to separate protein and enzyme, catalyst for alcohol dehydration, methane oxidation, and special powders to build artificial teeth and bone(Elliott, 1994). The properties of the surfaces of the HAP, for the example, the functional groups, acidity and alkalinity, surface charge, hydrophilic and is porosity. This has caused CA-HAP surface with P-OH groups, as adsorption sites be considered (Tanaka *et al.,* 2005). Absorption properties of HAP are of great importance for both environmental processes and industrial objectives. As a result of high absorption capacity, low immiscibility, high stability, oxidative capacity, availability and low costs it is considered an ideal material for controlling pollutants for a long period of time[18]. HAP stabilizes a wide range of metals such as chrome, cobalt, copper, cadmium, zinc, nickel, plutonium, lead, arsenic (U & V) used by many researchers (Czerniczyniec et al., 2003; Vega et al., 1999; Omar and Al-Itawi, 2007). They are absorbed through ion exchange reaction, the complex levels phosphate, calcium and hydroxyl groups or precipitation of new phases, some solutions have been reported.

In this project, the micro-scale Hydroxyapatite particles for the removal of heavy metals (Pb, Cd, Zn, Ni, Fe) was used.

MATERIALS AND METHODS

In order to examine removal capacity in media with variable concentrations of lead (0.08 to 0.76 ppm), cadmium (0.07 to 0.04 ppm), zinc (0.0048 to 0.0594 ppm), iron (0.004 to 0.343 ppm) and nickel (0.004 to 0.283 ppm) samples were prepared by adding 3 grams of hydroxy-apatite (Sigma-aldrich) to a 100 ml solution of samples in laboratory temperature. After mixing by a magnetic mixer substances were exposed to ultrasonic waves to disperse microparticles. Then, the fluid mixture and hydroxy-apatite were transferred to centrifuge device and the hydroxy-apatite suspended in the fluid was removed from water. Finally, solutions separated from studied sediments undergone atomic absorption.

Data Analysis and Statistical Method

Having experiments performed and absorption measured in samples and data obtained by SPSS16 software and T-test, data were analyzed and Excel software was used to depict charts.

RESULTS AND DISCUSSION

When hydroxy-apatite microparticles were added to samples and data were reanalyzed by atomic absorption device, the following equation for removal of heavy metals was used:

$$\% \text{ Removal} = \frac{(C_i - C_f)}{C_i} \times 100$$

C_i = Initial concentration, C_f = Secondary concentration

According to such a parameter which is the result of subtraction of an element\s initial concentration in water from the measured concentration after adding hydroxy-apatite microparticles in fluid the absorption percentage of various heavy metals by hydroxy-apatite can be estimated. Table 1, presents average percentage analyzed heavy metals absorption and Fig. 1, shows absorption of heavy metals by different concentrations of hydroxy-apatite.

Statistical studies using T-test for statistical comparison between various elements performed before and after adding hydroxy-apatite showed that there is a significant difference in lead's absorption percentage before adding hydroxy-apatite as a result of wide change domain in absorption percentage of various samples.

Cadmium and copper showed a significant difference before and after addition of the chemical which was the result of wide change domain of absorption percentage. This wide range, in turn, originates from variable factors such as pH, as evident in lead. Considering the wide change domain of absorption percentage which, here, is not the result of variables such as pH, zinc and nickel and iron showed no significant difference before and after addition of the chemical and their absorption percentage by hydroxy-apatite is considerably high.

Table 1: Average percentage of analyzed heavy metals absorption

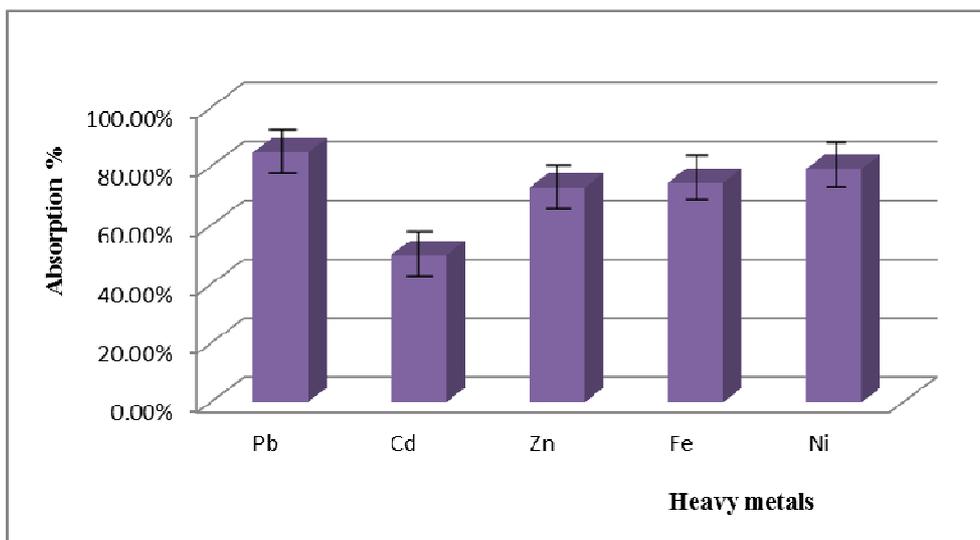|	R% Pb	R% Cd	R% Zn	R% Fe	R% Ni
Average absorption percentage	84.72%	49.89%	72.90%	74.50%	79.25%

Fig. 1: Different concentrations of heavy metals absorbed by the micro-particles of Hydroxyapatite

CONCLUSION

The present paper examined the effect of hydroxy-apatite in removal of heavy metals solved in water in laboratory conditions. Addition of hydroxy-apatite microparticles led to a high absorption of heavy metals and is was evident that it follows pH in some cases while absorbing lead, cadmium and copper. This means that a decline in solution pH decreases absorption percentage of these elements by hydroxy-apatite. But zinc, iron and nickel do not follow pH during absorption and hydroxy-apatite highly absorbs them. The reason for such performance is the presence if foundations with negative charge of phosphate and hydroxy in hydroxy-apatite (which are considered as hard Louise alkaline). Lead cation has a harder Louise acid than other cations. The other reason for the increase in absorption is electro-negativity or electron killing power of cations. Hence, it is possible to remove heavy metals of water in high pH using hydroxy-apatite.

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