REMOVAL OF HEAVY METALS FROM AQUEOUS SOLUTIONS USING *ACTIVATED CARBON*

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Abstract. A carbon used for the filtration of fresh water was activated using HCl and tested its capacity of heavy metals (Cd, Ni and Pb) removal from aqueous solutions. The initial concentration of heavy metals was 5 mg/L and the adsorption experiments were conducting using different quantity of sorbent (from 2.5 g to 20 g). The equilibrium was touched using the right relation between the sorbent quantity and exposure time. The obtaining activated carbon was successfully applied for adsorptive removal of Cd, Ni and Pb from stock solutions. The degree of decrease of the three metals was in the order of Pb>Cd>Ni.

Keywords: activated carbon, heavy metals removal, lead, nickel, cadmium

INTRODUCTION

One of the major issues of the environment is water quality deterioration caused by the discharged of wastewater. Wastewater can contain serious harmful substances, included heavy metals. Nowadays, heavy metals pollution has become a threat and has a great potential to cause environmental-derived cancer (Al-Qahtani, 2016), because those metals are non-biodegradable. In these unsafe metals category are included lead, nickel and cadmium, which are very dangerous at remarkably low concentrations.

Lead (Pb) results from a variety of human activities, such as mining, smelting, printing, metal plating, explosive manufacturing, dying, and consumer products such as paints, plastics, alloys, batteries, ceramic glass etc. All the chemicals that contain Pb are considered extremely dangerous (Ananthaa and Kotab, 2016). For the drinking water, the concentration of Pb should not exceed 10 µg/L, according to the World Health Organization (WHO, 2008). The side effects of the Pb over the human healthiness are physiological damage to kidney, nervous system, reproductive system, liver and brain, sterility, abortions, stillbirths and neonatal deaths(Ananthaa and Kotab, 2016).

Nickel (Ni) is another example of this metal category. It comes from many industrial applications such as mineral processing, electroplating, production of paints and batteries, manufacturing of sulfate and porcelain enameling (Lakhdhar et al., 2016). Ni is known as a hazardous element which can cause severely kidney damage, gastrointestinal distress and lungs disorder (Garg et al., 2008).

Like other heavy metals, cadmium (Cd) is introduced in the environment by a series of anthropic activities, such as: discharges from mining, batteries, metal plating, plastic and paper industries (Cheung et al., 2000). It can produce nausea, vomiting and serious kidney damage, like: renal dysfunction, hypertension and anaemia.

Removal of heavy metals from the aqueous solutes can be performed by conventional techniques such as filtration and membrane processes, electro-dialysis and chemical precipitation. The major problem of those heavy metals removal technics are their high costs for method`s implementation and operation (Ananthaa and Kotab, 2016).

Another way to remove heavy metals from the aqueous solutes is the adsorption of those metals into a suitable sorbent. Activated carbon (AC) is characterized by a high surface area, physicochemical stability, porosity, sorption capacity (Konga et al., 2015). AC is seen as the most widely used sorbent in water and wastewater treatment in the world, because of its low price and high accessibility.

The main objective of this paper was to test the ability of activated carbon to remove heavy metals (Cd, Ni and Pb) from water by batch adsorption method.

MATERIALS AND METHODS

HNO_3 65 %, HCl 1N and carbon used for this study were of p.a. grade and purchased from Merck, Germany. The standard solutions for instruments calibration were prepared from multi-element stock standard solution 1000 mg/L, while the batch adsorption tests were performed using mono-element stock solutions of 1000 mg/L Cd, Ni and Pb (Merck, Germany). All glassware was cleaned with nitric acid prior to use. All solutions were prepared using ultrapure water (18.2 MΩ/cm) obtained from a Millipore Direct-Q3 UV system (Millipore, France).

To obtain a higher adsorbing capacity, the *carbon* was activated: the sample was washed with ultrapure water, acidified with HCl 1 N, for 24 hours. Then, the sample was centrifuged for 20 minutes at 3500 rpm and washed with ultrapure water. This step was repeated for 10 times. After centrifugation, the sample was dried in oven at 70 ºC for 24 hours (Souflias et al., 2008).

The experiments were conducted using 25 mL of heavy metal solutions of 5 mg/L (Cd, Ni and Pb) with different quantities of AC (from 2.5 g to 20 g) for different periods of time (5, 10, 15, 30, 45, 60, 120 and 180 minutes), at room temperature. The samples were centrifuged using UNIVERSAL 320 benchtop centrifuge, filtrated with 0.45 µm membrane filters, washed with ultrapure water and acidified with HNO_3 65 %. The residual heavy metals were determined using an Optima 5300 DV Perkin Elmer ICP-OES.

The amount of heavy metals absorbed per unit mass of AC was determined using Eq. 1 and the removal efficiency of the sorbent was calculated using Eq. 2.

$$q_e = \frac{(C_0 - C_a)}{m} \cdot \frac{V}{1000} \quad (1)$$

$$E(\%) = \frac{(C_0 - C_a)}{C_0} \cdot 100 \quad (2)$$

where C_0 - initial concentration of stock sample (mg/L)

C_a - the final concentration of stock sample after adsorption (mg/L)

q_e - amount of heavy metal adsorbed onto the AC (mg/g)

V - volume of the medium (mL)

m - amount of the AC (g)

E - removal efficiency (%) (Lakhdhar et al., 2016).

RESULTS AND DISCUSSIONS

Effect of weight of activated carbon on the removal of the heavy metal

The experiments were carried out using three stock solutions: 5 mg/L stock solution of Cd, Ni and Pb, respectively, with different quantities of *activate*d *carbon* (2.5, 5, 10, 15 and 20 g) for 60 minutes. The sorbent efficiency for the adsorption of heavy metal is presented in Fig. 1.

The most efficient extraction of heavy metals was in the case of Pb, using 10 g AC at approximately 0.2 mg of Pb in the aqueous solution. In this case, the extraction performance was 99.78 %.

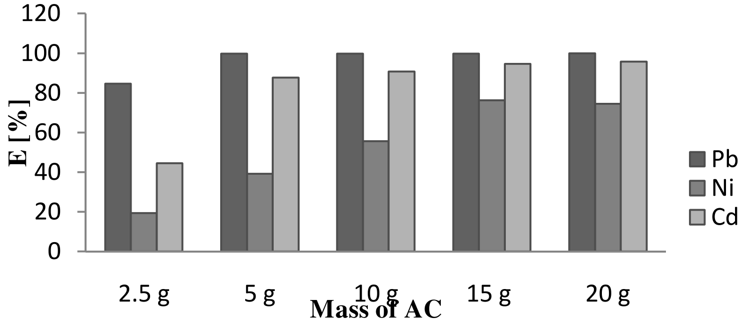

Fig.1. The removal efficiency and amount of heavy metals adsorbed onto *AC* at different quantities of sorbent

In the case of Ni adsorption onto AC, with different quantities of AC, it was notice that a high efficiency was reached when it was used 15 g AC at 25 mL of 5 mg/L Ni solution. The removal efficiency of 76.0 % was lower than in the case of other metals` adsorption (Fig. 1). In addition, watching the variation of the quantity of Ni adsorbed onto the AC, it can be clearly observed an exponentially increase of the value of the removal efficiency when it was used a higher quantity of AC.

The experiment involving Cd extraction with different quantities of AC revealed that the most profitable situation of extraction was when it was used 5 g AC at 25 ml solution of 5 mg/L Cd. In the case of Cd, the growth of the heavy metal removal efficiency was not as clearly as in the case of Ni adsorption, but an increasing of the efficiency value could be notice.

Effect of contact time on the removal of the heavy metal

To determinate the moment when the system reaches the equilibrium, series of experiments were conducted. A batch of 25 mL sample of 5 mg/L Cd, Ni and Pb solution was subjected to 2.5 g and 10 g of AC for 5, 10, 15, 30, 45, 60, 120 and 180 minutes. The effect of contact time (from 0 to 180 min) on the adsorption of Cd, Ni and Pb is showed in Fig. 2 and 3.

Using 2.5 g of AC, the equilibrium was established after 60 minutes with a Pb removal efficiency of 75 %, and the calculate amount of heavy metal adsorbed onto AC has values between 0.11 and 4.29 mg of Pb / g AC (Fig. 2). On the other hand, using 10 g AC, the amount of Pb adsorbed onto the AC was in the percentage of 99.8, even if the state of equilibrium was established as in the previous situation (Fig. 3). In both cases, it can be notice that the efficiency removal chart curve was in an exponential ascension until it reached the equilibrium. Ibrahima et al., 2006 showed that for Pb adsorption, the system`s equilibrium is reached after 60 minutes and the removal efficiency is almost 100 %.

In the case of Ni, the equilibrium was established at a very high heavy metal`s concentration remained in the solution. Fig. 2 and 3 show that, using 2.5 g and 10 g of AC, equilibrium is obtain after 120 minutes in the case of 2.5 g of AC and 60 minutes in the case of 10 g of AC. At the end of the experiments, in the final solution, there was left a considerable quantity of Ni, 65 % at least. Karnib et al. 2014 presented that the Ni removal efficiency is 90 % almost double that the result of the experiments.

The conducted experiments concluded that, in the case of Cd adsorption, the removal efficiency was 97 %. In case of using 2.5 g AC, the adsorption factor had a value of 0.47 and in the case of using 10 g AC, the Cd adsorption was almost 100 %. In the first case, the system`s equilibrium was reached after 150 minutes, and in the second scenario, after 100 minutes. The values of removal efficiency of Cd are, also, similar to other studies. The authors of other studies reports a high Cd removal efficiency of the activated carbon, which reaches values of 90 % (Karnib et al., 2014).

Using a mixture containing magnetic carbon nanotubes and diatomite earth, the removal efficiency of Pb is a little bit lower that in the case of activated carbon removal. With that mixture used as a sorbent, the removal coefficient is around 75 %, way lower that in the case of AC (Alijania et al, 2014).

Another adsorbent used to remove the heavy metals from the aqueous solutions is nanocomposite materials. In contrast to the conventional sorbent (activated carbon, carbon nanotubes, mesoporous silica, aluminium oxides and zero-valent iron), the heavy metals can be separated from the sorbent. Using mixture between Fe_3O_4 and MnO_2, the Pb removal coefficient is almost 100 %, the Cd removal coefficient is around 90 % and for Ni, the coefficient is around 70 % (Zhaoa et al., 2016).

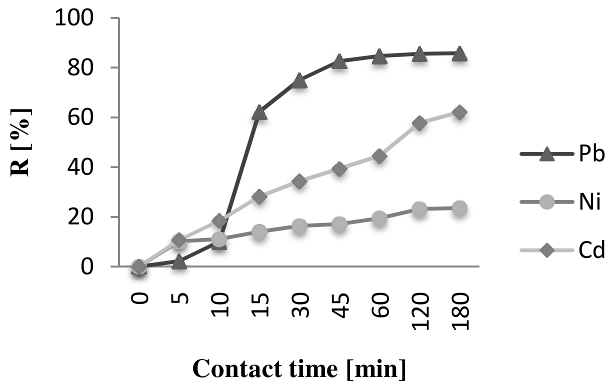

Fig.2. The removal efficiency and amount of heavy metals adsorbed onto 2.5 g of *AC* at different contact time

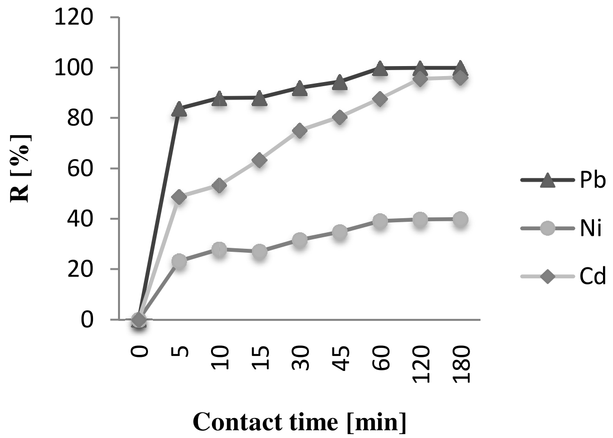

Fig. 3. The removal efficiency and amount of heavy metals adsorbed onto 10 g of *AC* at different contact time

The obtained results indicate that the removal of heavy metals like Cd, Ni and Pb through the adsorption onto activated carbon can be applied to purify drinking water and industrial wastewater from heavy metals.

CONCLUSIONS

Activated carbon was used as an adsorbent for the removal of some heavy metals from aqueous solution. The obtained results indicated that AC is a good sorbent for heavy metals, with a high efficiency. For every metal which was tested, the removal efficiency was 50 % and higher. Cd and Pb were adsorbed onto AC almost entirely after 60 minutes and Ni was 80 % removed. Therefore, it can be concluded that activated carbon was the most effective for nickel removal and it is highly recommended to be used in water treatment for its high adsorptive capacity. The developed and method has a big advantage: a high removal efficiency.

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