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Phytoremediation of Heavy Metals from Wastewater Using Bean Plants

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The Bean Plants were used in this work as low cost adsorbent material for removal of Pb(II), Cd(II) and Zn(II) ions from aqueous solutions. The samples were prepared and sorted according to the particles diameter by standard sieves 250 - 500 μm. Batch adsorption experiments were carried out to study the adsorption process pH of adsorbent, effect of contact time, effect of adsorbent amount and effect of metal concentration were Investigated in these experiments. The effect of any one of those previously mentioned parameters on the adsorption capacity were studied while the other parameters were kept constant. The maximum adsorption capacities of beans for the removal of selected heavy metals were very high. It is suggested to use it as a low coast adsorbent material to clean up the water in the environment from toxic heavy metals.

Key words: Adsorption Capacity; Heavy Metals; Adsorbent; Wastewater Treatment; Fava Beans.

Water pollution by heavy metals has been a major concern for and environmental scientist's as it affects public health. Heavy metals are non-biodegradability and they accumulate in living tissues. They cause various diseases and disorder for many living organisms (Kirk & Laster, 1984; Orhan, 1990, Almeelbi *et al*., 2014; El-Saharty & Hassan, 2014). In many countries, the levels of industrial pollution have been steadily rising, and the pollution problem of industrial wastewater is becoming more serious in the world. Therefore, the treatment of polluted industrial wastewater remains a topic of global concern. At least 20 metals are classified as toxic and half of these are emitted into the environment in quantities that pose risk to humans health (Dawri *et al*., 2004; Park & Yung 2001). Different technologies have been used for the removal of heavy metals from wastewater. They mainly include: precipitation, ion exchange, membrane processes, evaporation, chemical oxidation or reduction, solvent extraction and biological materials. These techniques are very expensive and economically unfavorable or technically complicated, and are use only in special cases of wastewater treatment (Abdel Halim, *et al*., 2003; Qadeer *et al*., 2007; Qari & Hassan, 2014)]. Relatively a new green technology for the treatment of industrial wastewater was adsorption of heavy metals and dyes from aqueous solutions by using natural material. Adsorption process has been proved to be an excellent way to treat industrial waste effluents, offering significant advantages like the low cost, availability, profitability, easy operation, and efficiency (Amuda *et al*., 2007; Gupta & Babua, 2005;Shin & Rowell, 2005)

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In addition, adsorbent of heavy metal could be selective for some metal ions (Hashem 2007).

In the present work, the Fava beans were used as adsorbent material for removal of Pb(II), Cd(II)and Zn(II) ions from aqueous solutions and wastewater samples. Fava beans are one of the oldest plants under cultivation, and they are eaten in ancient Greece and Rome. Despite the name, fava beans are a member of the pea family, though they are also known as broad beans, pigeon beans, horse beans, and windsor beans. They are popular in Mediterranean cuisine, with many summer dishes celebrating the seasonal bean, although they are also dried for winter use. Fava beans have a distinct flavor and creamy texture that makes them a great addition to a wide variety of dishes Hashem *et al.*, 2007).

MATERIALS AND METHODS

Bean plants purchased from commercial source and washed several times with tap water, then by distilled water and then dried in oven at 80ÚC - for 24 h. The samples were ground in mortar and passed through 250 - 500 m standard sieves. Then, the powder was washed with distilled water and dried in an oven at 60ÚC for 6 h,. and kept in plastic-stopper bottle . The standard solutions of metal ion (Pb and Cd. (1000 mg/L) were provided from BDH Company. 100 ml of the stock standard solution of the selected ion diluted in 1000ml distilled water . Then 5 ml of this solution was dissolved in 50 ml with deionized water to get a final Concentration of 10 mg/l selected ion. pH of solution was adjusted using 0.1 M HCl. All the adsorption experiments were carried out at room temperature.

The stock solution of Zinc was prepared by dissolving 45.5 g of zinc powder in 1000 ml distilled water. EDTA standard solution was prepared by drying 250 gm in an oven at 80ÚC for 10 h then dissolving it in a 100 ml distilled water. The concentrations at equilibrium, of Pb(II) and Cd(II) were determined using atomic absorption spectrophotometer, after calibrating the instrument with standards within the range of 6 - 10 ppm Pb^{2+} and 0.1 - 1.5 ppm Cd^{2}+ (Qari and Hassan, 2014)).

The conical flasks were shaken for 1:30h at 175 rpm using mechanical shaker for (15, 30, 45, 60, 75, 90 min) then the filtrate was analyzed for Pb(II) and Cd(II) by flame AAS and by compleximetric titration for Zn against EDTA.

RESULTS AND DISCUSSION

Effect of pH

The higher adsorption capacities were attained at pH 3.0 for Pb (II) (Fig 1.), pH 4.5 for Cd (II) (Fig 2.), and pH 4 for Zn(II) ions (Fig. 3). The adsorption capacity of Pb(II), Cd(II) and Zn(II) ions onto beans was increased as the pH increased till the optimum pH, after that the pH decreased, this happened because for the adsorption sites and solubility product for every metal ion.

pH has been reported as one of the major parameters controlling the adsorption capacity of metals onto adsorbents ,it affects the solubility of the metal ions, the degree of the (Badnus *et al.*, 2007; Karri *et al.*, 2008) of the ionization of the adsorbent during reaction and concentration of the counter of the functional groups of the adsorbent.(Hashem *et al.*, 2007; Karri *et al.*, 2008)

Effect of Contact Time

It is clear from Figures 4-6 that, the adsorption capacity of Pb(II), Cd(II) and Zn(II) ions by beans increases as the contact time increases and reached the equilibrium state.

The contact time is one of an effective factors in batch adsorption process and it is essential to evaluate the effect of contact time required to reach equilibrium.

Effect of Adsorbent Quantity

The effect of adsorbent amount on metal ion adsorption was studied by preparing (50 ml of 10 ppm) solutions of Pb(II) and Cd(II) containing different doses adsorbent (0.1,0.3,0.5,0.7,1.0 and 2.0 gram),as shown in Table 3, after shaking the solutions were filtered and the filtrates were analyzed by using(AAS) and % removal efficiency was calculated for each case. Zn analyzed by compleximetric titration against EDTA. The effect of adsorbent quantity on the adsorbent capacity of Pb(II), Cd(II) and Zn(II) is shown in the following figures.

Effect of Initial Metal Concentration

The effect of metal concentration was studied by adding 0.5 g of beans to 50 ml of heavy metal concentrations of (5ppm,10ppm ,15 ppm, 50 ppm, 100 ppm) at pH = 3.0 for Pb(II) and pH 4.0 for Cd(II) (Fig 7).

The adsorption capacity of Pb(II), Cd(II) and Zn(II) ions onto Fava beans increased with increase in initial concentration of metal ions. It means that the adsorption is highly dependent on initial concentration of metal ions. This is because at lower concentration, the ratio of initial number of metal ions to the available surface area is low; subsequently the fractional adsorption sites

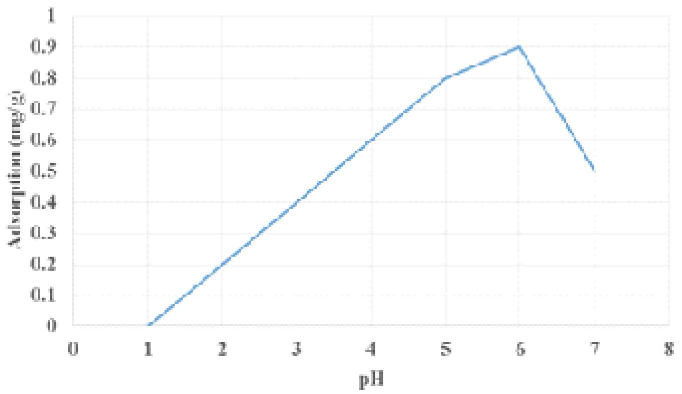

Fig. 1. Relationship Between pH and adsorption ability of Pb(II) onto beans

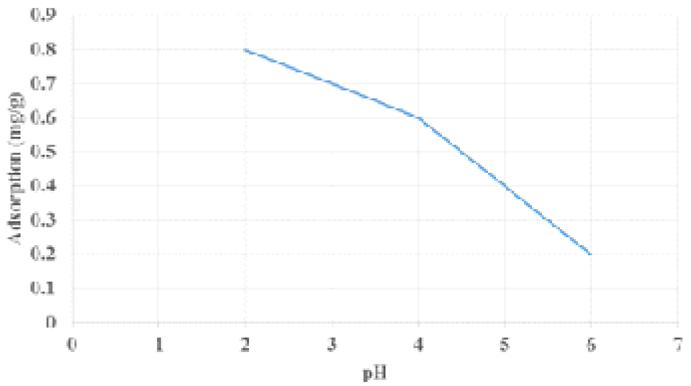

Fig. 2. Relationship Between pH and adsorption ability of Cd(II) onto beans

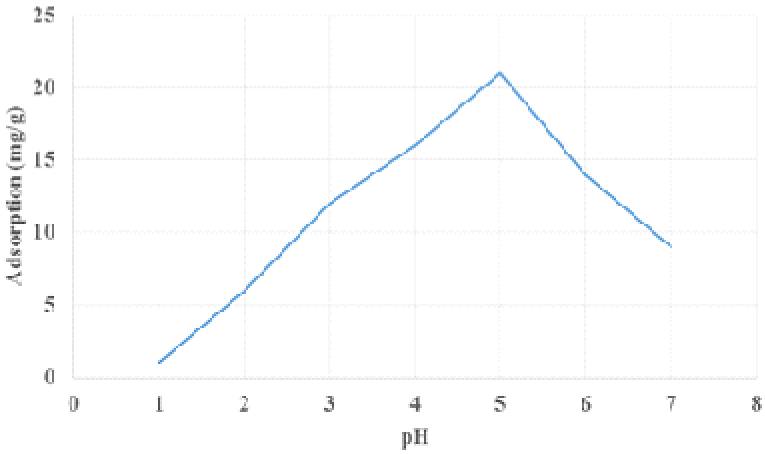

Fig. 3. Relationship Between pH and adsorption ability of Zn(II) onto beans

become independent of initial concentration. However, at high concentration the available sites of adsorption becomes fewer and hence the adsorption of metal ions is dependent upon initial concentration (Badnus *et al.*, 2007) (Fig 8-10). The correlation coefficients for the calibration curves

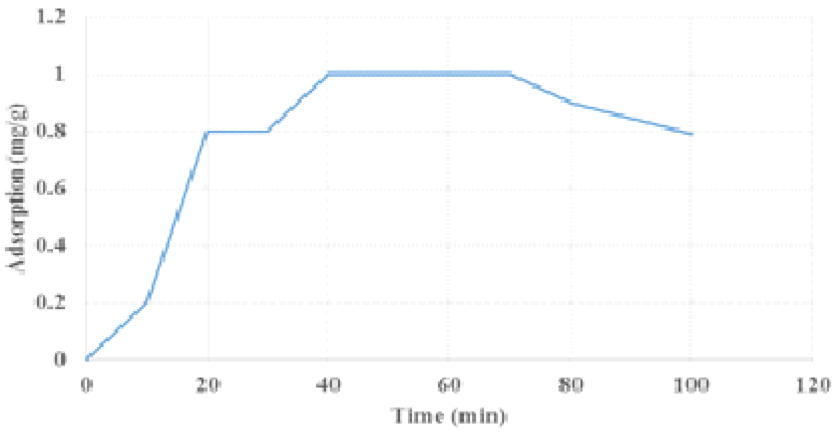

Fig. 4. Changes of adsorption Pb(II) with time

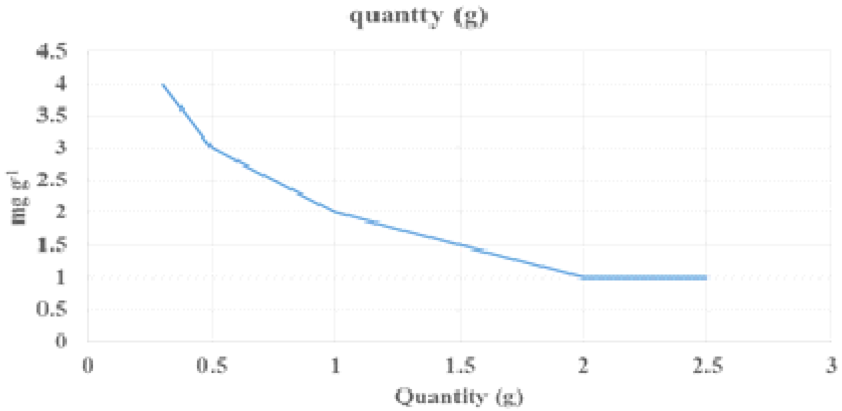

Fig. 5. Reducing quantity adsorbent with increasing adsorption capacity of Pb

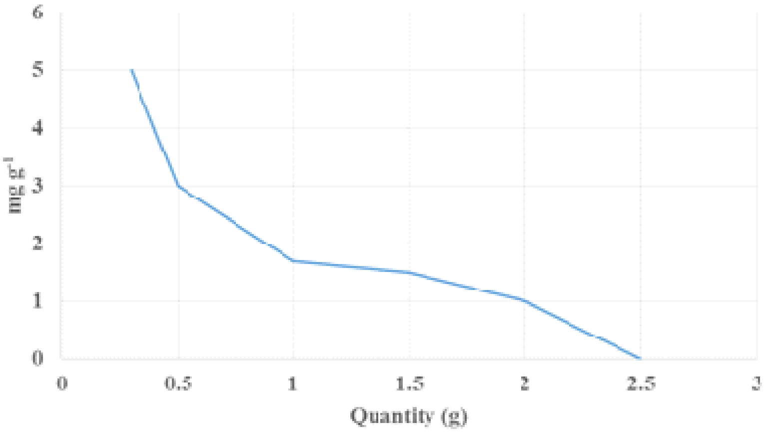

Fig. 6. Reducing quantity adsorbent with increasing adsorption capacity of Cd

were 0.998 and 1.00 for $Pb^{2}+$ and $Cd^{2}+$ respectively.

Langmuir Adsorption Isotherm

The Langmuir adsorption isotherm is the best known linear model for monolayer adsorption and most frequently utilized to determine the adsorption parameters. The Langmuir isotherms are based on these assumptions Langmuir Karri *et al*., 2014)]. The linear form of the Langmuir equation is giving:

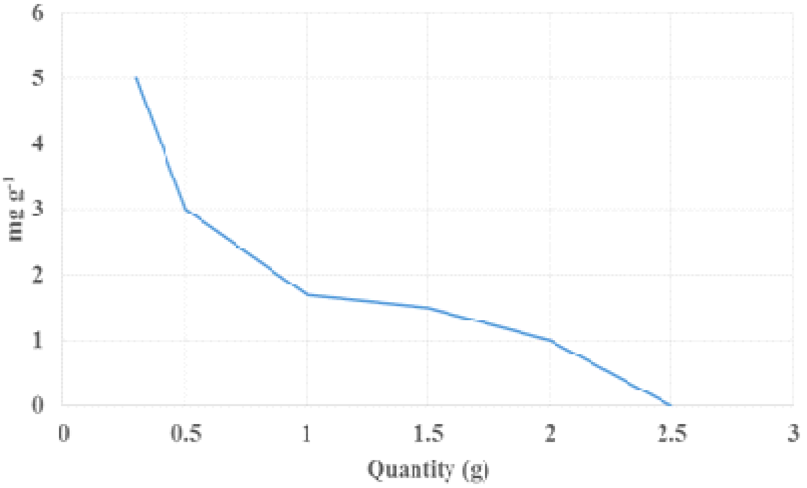

Fig. 7. Reducing quantity adsorbent with increasing adsorption capacity of Zn

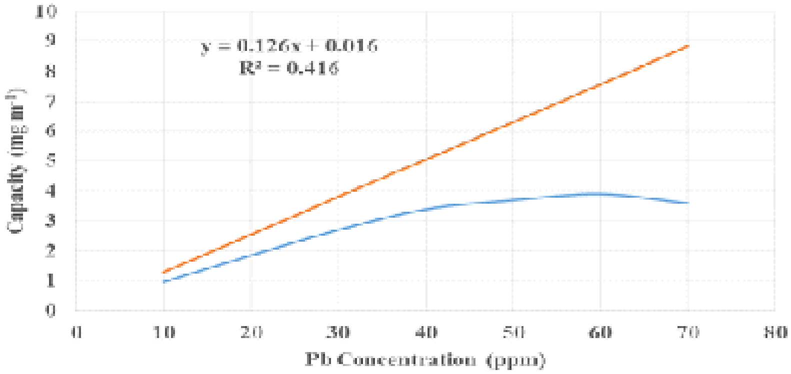

Fig. 8. Regression of Pb concentrations on adsorption capacity

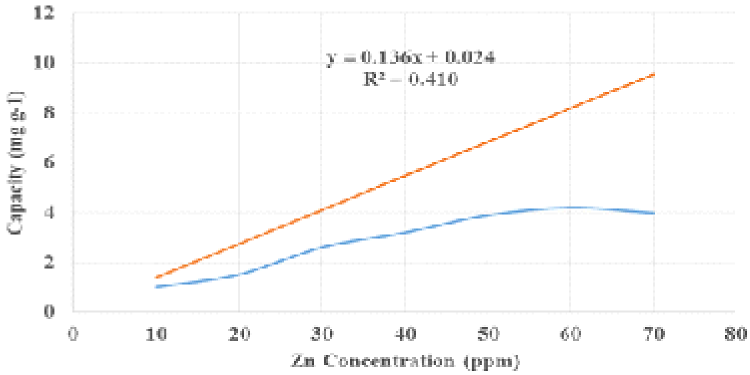

Fig. 9. Regression of Cd concentrations on adsorption capacity

$$q = \frac{kl\ ce}{1 + aT\ Ce} +$$

where q (mg/g) is the amount of metal ions adsorbed onto the unit mass of the adsorbent to form a complete monolayer on the surface. KL is the Langmuir equilibrium constant which is related to the affinity of binding sites; Ce the solution phase metal ion concentration, and αL is the Langmuir constant. The constants KL and αL are the characteristics of the Langmuir equation and can be determined from linearized form of the

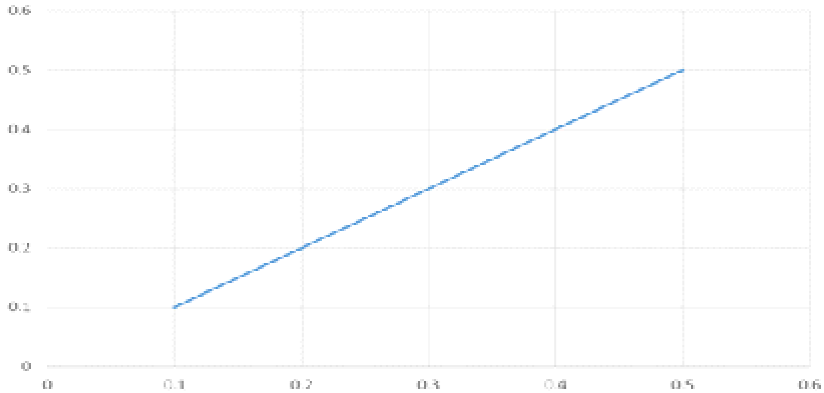

Fig. 10. Regression of Zn concentrations on adsorption capacity

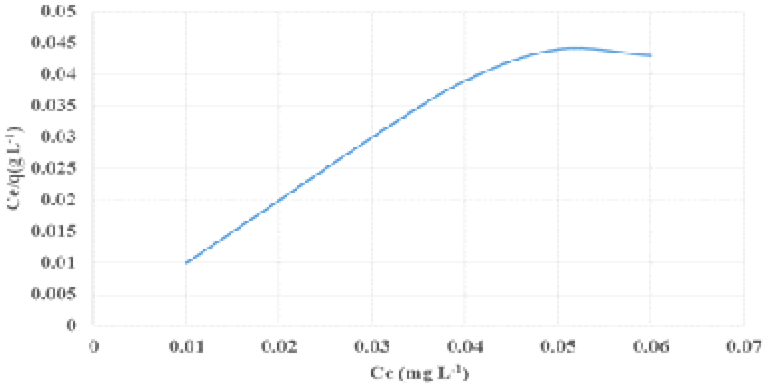

Fig. 11. Adsorption isotherm of Cd

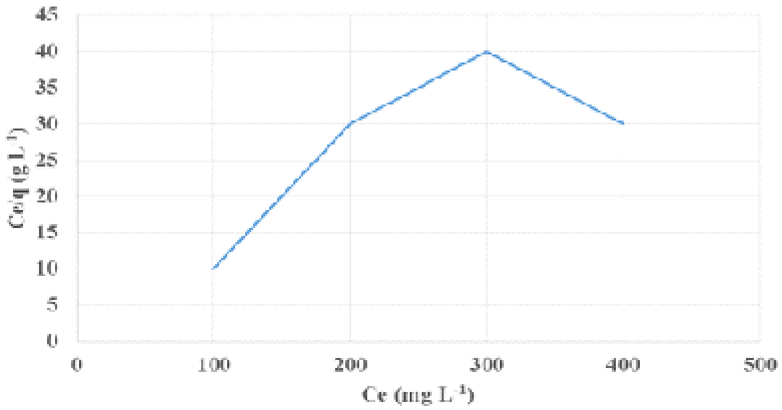

Fig. 12. Adsorption isotherm of Zn

Langmuir equation .The plots of Ce/q against Ce are presented in Figures 11-12 for adsorption of Pb(II), Cd(II) and Zn(II) ions onto beans at room temperature.

Removal of Lead from Wastewater from west Alexandria (applications)

The procedure was applied to wastewater, employing Fava beans as the removing material. The real sample was Collected from West Alexandria Factories Several steps are involved in the electroplating process. One of them, the wash after the electrolytic bath, and the efficiency of this step have repercussion in the quality of the final product and the electrolytic bath composition. For the control of this composition, the purity of the water used in the cleaning processes is necessary, and high volumes of water are used. This water must be therefore treated by a depuration system before it is recovered or removed, although the concentration of corresponding metallic ion is relatively low. Real sample of wastewater was taken from inside batteries factory. This sample was treated under the best conditions to remove Pb(II), where pH = 3.0, contact time was 1:30 h and adsorbent concentration was 0.5 g (Etrokia *et al*., 2014).

$$\text{Removal \%} = \frac{19.3 - 1.003}{193.3} \times 100 = 89.014$$

In Conclusion**,** the adsorption capacity of metal ions was found dependent on initial pH, contact time, adsorbent amount and metal concentration of heavy metal. The obtained maximum adsorption capacity of Fava beans for removal of selected heavy metals was 100% for Pb(II), 92.86% for Cd(II) and 36.86 for Zn(II) at 2 g dose amount of Fava beans powder. The experimental results for all target metal ions were fitted very well to Langmuir mathematical equation.

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