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Examining temperature effect on the adsorption and desorption of cadmium from soil surfaces and the best adsorption equation

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Abstract

In recent years, due to their simplicity, being relatively low price and also being reasonable and effective in the removal of heavy metal ions from wastewater, adsorption-based methods are of most interest. The objective of this research was studying adsorption isotherm of cadmium in the field's soil of Amir- Kabir Sugarcane Crops And Industry Company. The study was done in factorial design consisted of four treatments in a randomized block, including: T_0: The Company fields soil as control T_1: Treatment with 50 mg per kg of cadmium from the Cd (NO_3) source, T_2: Treatment with 100 kg of cadmium from the Cd (NO_3) source and T_3: 150 milligrams per kilogram of cadmium from the source Cd (NO_3) in 12 pots for each experiment, at three temperatures of minimum, average and maximum 16.6, 24.8 and 33.3, for the cultivation period in Amir-Kabir sugar cane cultivation and Technology Company was performed. The results showed that there was a significant difference between temperature, concentration, and interaction of temperature and concentration on adsorbable cadmium in soil at 1% test Duncan level. Such that, for the treatments of T_1C_4 and T_3C_3 the minimum and maximum soil adsorbable cadmium which being (0.1 and 31.41) were obtained, respectively. Adsorption data obtained by both Freundlich and Langmuir equation were fitted and their coefficients were calculated. Among both equations, The Freundlich equation describes adsorption behavior of cadmium in the soil in question better than the Langmuir one.

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Introduction

There are various methods for reducing the pollution of soil and water and remove heavy metals such as cadmium, among which the most important are chemical precipitation, evaporation, solvent extraction, membrane processes, adsorption and ion exchange. But many of these methods are often time-consuming, high cost and low efficiency, so just a few of them are acceptable for many pollutants.

Cadmium is one of the heavy metals that due to its potential to damage human health and Animals, in recent decades gained so much interest for Environmental issues and it tried to avoid it from entering the environment cycle as much as possible. Naturally in annual 25,000 tons of cadmium, about half of which comes from the weathering of rocks of planet earth, enter into the environment (Kabata & Pendias, 2000)

At present, there are various methods for reducing the pollution of soil and water and remove heavy metals such as cadmium, among which the most important are chemical precipitation, evaporation, solvent extraction, membrane processes, adsorption and ion exchange (Wilde & Benmann, 1993).

But many of these methods are often time-consuming, high cost and low efficiency, so just a few of them are acceptable for many pollutants. In recent years, methods based on adsorption due to its simplicity, their relatively low price and also being appropriate and effective in removal of heavy metal ions from wastewater are of most interest. In these methods, to remove contaminants a suitable adsorbent could be used. Adsorption of ions in the soil, using adsorption isotherm equations provides us useful information about the soil retention capacity and soil Metals absorption in soil. Due to soil heterogeneous characteristics and minerals diversity in soil, with studying of elements interaction with each one of the components of the soil, the role of different solid phases in fate of heavy metals can be investigated separately (Mojalali, 1987). The aim of this research was studying adsorption isotherm of cadmium in the field's soil of Amir- Kabir Sugarcane Crops And Industry Company. This study was done in factorial design consisted of four treatments in a randomized block.

Materials and methods

The area under study

Amir Kabir Agriculture and Technology Company is one of the seven units of the Sugarcane Development and Side Industries Company of sugar cane.

Experiment method

This experiment was done in a randomized block with factorial design with four concentration treatments, including, T_0: The Company fields soil as control T_1: Treatment with 50 mg per kg of cadmium from the Cd (NO_3) source, T_2: Treatment with 100 kg of cadmium from the Cd (NO_3) source and T_3: 150 milligrams per kilogram of cadmium from the source Cd (NO_3) in 12 pots for each experiment, at three temperatures of minimum, average and maximum 16.6, 24.8 and 33.3, for the cultivation period in Amir-Kabir sugar cane cultivation and Technology Company was performed.

Laboratory Section

After preparing the samples and placing them into incubator, moisture of samples were monitored in daily manner so that they reach to an appropriate field capacity. After 3 weeks, all the pots were sampled, and in order to determine the concentration of cadmium absorbed by the solution DTPA, extraction was done and it was read by atomic absorption device.

Method of Soil Analyses

Also, the chemical and physical properties of soil, including, particle size percent using hydrometric method, pH in saturation mud using pH meter, electric conduction in saturation mud using extracts by ohmmeter, CEC using ammonium acetate 1 normal method and replacement by using Sodium acetate

and reading by using flame photometer, lime percent using back titration using hydrochloric acid and soda 1 normal, evaluated by the percentage of soil organic matters using back distillation in soil method, were determined, and ultimately, the obtained data were analyzed by MSTACT software, and related charts were drawn using Excel software. Finally, the obtained data were matched with Langmuir and Frundlich adsorption equations and the best equation was determined.

Results and discussions

Amount of matter adsorbed per unit mass of absorbing, is a function of the concentration of dissolved matter. Usually by increasing the ionic strength in the solution, the adsorption element rate decreases. Erickson (1989) reported that the higher ionic strength solution, the increased adsorption of cadmium. Garcia and Page (1976) in their studies reported this outcome as well. Also Spark (1995) stated that due to increased background electrolyte concentration, adsorption of zinc, copper, cobalt and cadmium by *Kaolinite* clay will decreases.

Temperature

Basically, unless the adsorption is accompanied by chemical reaction, increase in temperature reduces adsorption. Zavvar Mousavi *et al.* in a study carried out in order to absorb cadmium on Nano-Alumina concluded that when temperature increases, the amount of Cadmium Absorption By absorbing agent will decrease. After reviewing most of carried out Studies, it was found that On Different Absorbents, Absorption of Cadmium is Endothermic (Dong *et al*, 2010).

pH

Because that hydrogen ions or Hydroxides are strongly adsorbed, adsorption of other ions is governed by the pH of the solution. Adsorption of typical Organic Pollutants in water, commonly increases with decreasing pH.

Type of adsorbed and adsorbent materials and their State (Rashidi et al, 2013)

So far, several equations have been proposed to describe existing relationships, among which both Freundlich and Langmuir equations are used more than the other equations.

A) Lungmoir Equation

This equation was initially proposed for the adsorption of gases on solid surfaces and later it was being used to absorb fluids and ions on solid surfaces. Linear form of the equation is as follows:

$$\frac{ce}{qe} = \frac{1}{bq_{max}} + \frac{ce}{q_{max}} \quad (1\text{-}1$$

B) Frundlich equation

According to this equation, with increasing surface coverage (uptake rate), the absorbtion energy decreases exponentially.

Linear form of the equation is as follows:

$$\log qe = \log k_f + 1/n \log ce \quad (2\text{-}1)$$

(Malacouti & Homaee, 2004).

The results of Physical and chemical soil analysis are given in Table (1-1). According to this table, the Soil pH is in the range of neutral to alkaline, and the soil electrical conductivity is 1.19 Deci Siemens per meter. Removal of Cd at pH less than 8 predominantly controlled by the adsorption process. But we can expect that the value of pH greater than 8 significantly increases after deposition of cadmium hydroxide (Zavar Mousavi *et al*, 2011), the percentage of calcium carbonate (limestone), is 45% indicating that the soils are calcareous. There is a correlation between uptake of cadmium and limestone amount, and therefore the more the soil be calcareous, the more is adsorption (Gluberg & Forrester, 1991). Soil organic matter, was 4.2 percent and cation exchange capacity has been 11.87 mili Eqivalant per 100 g soil. Studied soil, had 72% sand, 14% silt and 14% clay and Sandy loam texture, according to the rule that the finer texture, the more specific surface area, thereby more adsorption, it is expected that because of being

sandy and coarse, the under study didn't show absorption peak.

Table 1. Some of physical and chemical properties of under study soil.

Percentage of soil particles	Soil	pH	% Lime	Organic matter	Salinity dS / M	Cation exchange capacity meq / 100gr
Sand: 72 Silt: 14 Clay: 14	Sandy loam	7.50	45	2.4	1.19	11.87

Comparison of average temperature effect on cadmium absorbed

The Results showed that temperature is of significant effect on absorbed cadmium. Based on previous statement, comparison of the average for absorbed concentration on different temperatures were carried out, as shown in Fig. (1-1) at the temperature of 16.6°C, the highest absorbed cadmium was measured, meaning that in this temperature, the highest adsorption has occurred, and there was not a significant different between the two temperatures of 24.8 and 33.3, regarding that the important physiological process of sugar-making and sugar-saving in sugarcane plant is carried out from April to November. During this period, according to meteorological report taken from weather station of Amir-Kabir Company, the temperature of 16.6°C is not governing in the region.

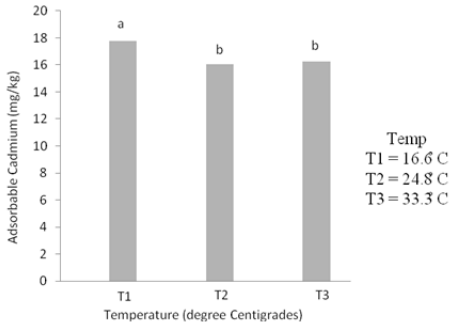

Fig. 1. Comparison of the average temperature effect on the adsorbable cadmium.

Comparison of mean concentration effect on adsorbable cadmium

The results showed that the concentration has significant effect on cadmium absorbed, on this basis, comparison of mean concentrations for absorbable cadmium concentration at different concentrations was carried out, and as shown in Fig. (2-1), at concentration of 150 ppm, absorbed cadmium was equal to 17.77 mg/kg, indicating the highest adsorption. Between both concentrations of 100 ppm and 50 ppm there is no difference. Cadmium concentration can be said to be directly related to the absorption so that the maximum amount of soluble cadmium in concentration 150 ppm equals to 17.77 and the minimum amount of absorbed cadmium in the control soil equals to 0.1.

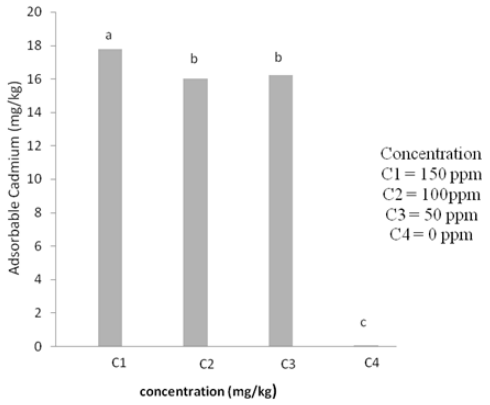

Fig. 2. Comparison of mean concentration effect on absorbed cadmium.

Comparison of temperature and concentration interaction mean effect on absorbed cadmium

The results showed a significant effect of interaction between temperature and concentration on absorbed cadmium. Accordingly, the comparison of mean effect on the interaction of temperature and concentration on absorbed cadmium was carried out. As seen in Fig. (3-1) in treatment of (T_1C_4 and T_3C_3), the lowest and highest adsorbable cadmium in soil (0.1 and 31.41) were observed, Respectively.

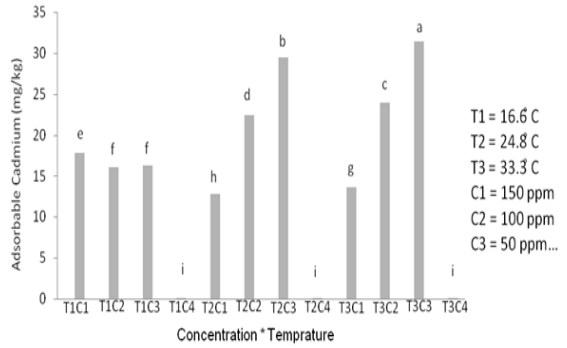

Fig. 3. Comparison of mean interaction effect of temperature and concentrations on absorbed cadmium.

Examining the Langmuir and Freundlich adsorption isotherm equations

adsorption equation

As mentioned above, isotherms show the relationship between the adsorption of element and its ion concentration in the equilibrium solution. So far, several equations have been proposed to describe existing relationships, among which both Freundlich and Langmuir equations are used more than the other equations.

Evaluating Langmuir isotherm adsorption equation in the under study soil in minimum, average and maximum temperatures

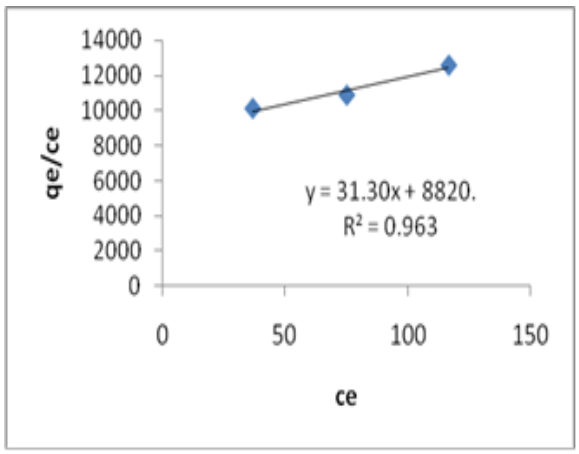

Fig. 4. Adsorption isotherms for cadmium element according to Langmuir equation in the under study soil at minimum temperature**.**

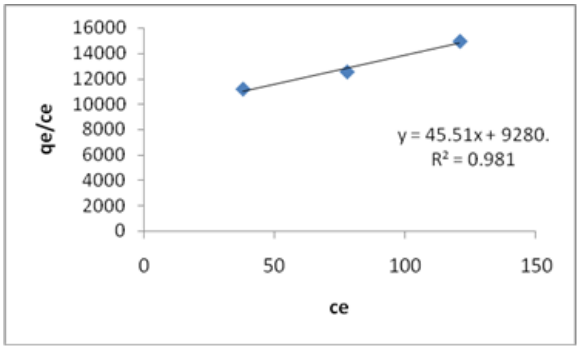

Fig. 5. Adsorption isotherms for cadmium element according to Langmuir equation in the under study soil at average temperature.

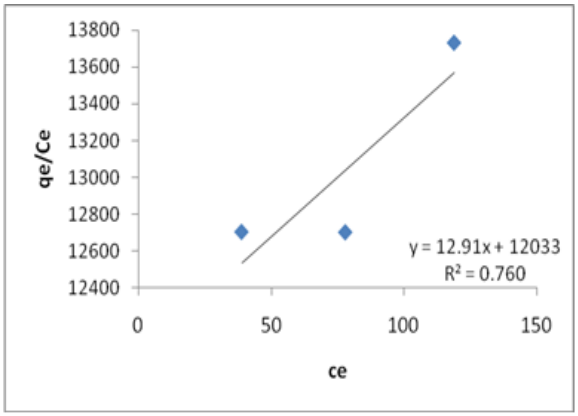

Fig. 6. Adsorption isotherms for cadmium element according to Langmuir equation in the under study soil at maximum temperature.

Evaluating Freundlich isotherm adsorption equation in the under study soil in minimum, average and maximum temperatures

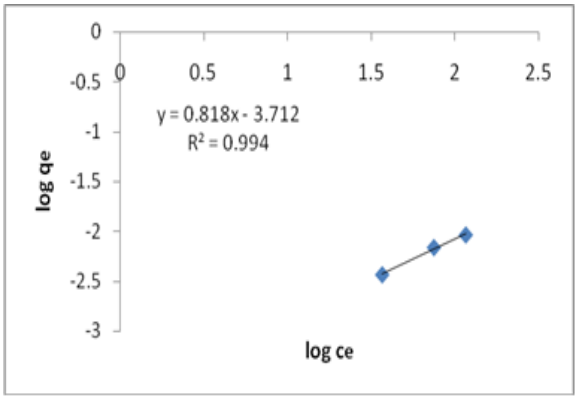

Fig. 7. Adsorption isotherms for cadmium element according to Freundlich equation in the under study soil at minimum temperature.

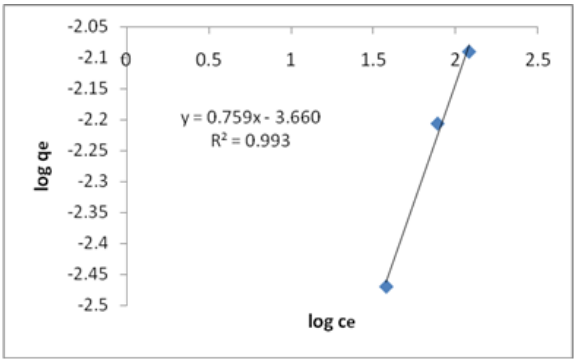

Fig. 8. Adsorption isotherms for cadmium element according to Freundlich equation in the under study soil at average temperature.

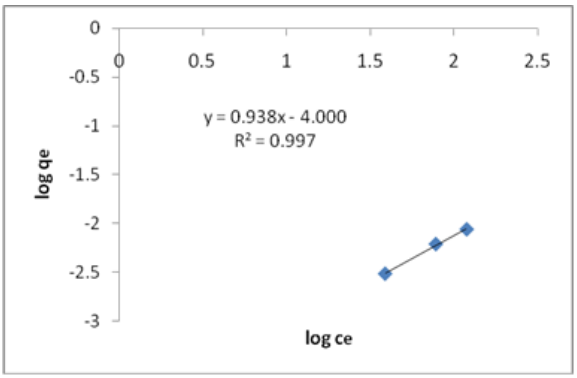

Fig. 9. Adsorption isotherms for cadmium element according to Freundlich equation in the under study soil at maximum temperature.

Conclusion

The results of fitting cadmium adsorption data obtained by Langmuir and Freundlich equation showed that both isotherms equations truly described cadmium adsorption trend. However, Freundlich equation has higher correlation coefficient than the Langmuir one, as a result this equation describes cadmium adsorption better than Langmuir. Charm & Daschle Brown (2007) also reached the same conclusion in investigating phosphorus adsorption in soils under sugarcane cultivation in the region of Sho'eibieh in Khuzestan, Iran and also Charm & Abdullahi (2005) in investigating zinc adsorption in soils of the sugarcane agriculture and industry company in North of province Khouzestan (Haft-Tapeh and Shoushtar).

Suggestions

1. Given that in this study, three concentration treatments were studied, it is suggested that in further studies in order to enhance test accuracy and precise fitting the adsorption isotherm equations, at least five concentration treatments to be used.

2. The concentrations used in this study were considered as high, so it is suggested that in future researches concentrations in the range of 5 ppm to be considered.

3. It is suggested that in future research, breakdown of soil at different times to be carried out.

4. It is recommended to repeat the study with regard to the above mentioned items, and its results are used to control the heavy metals.

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