

Sorptivity of Cd, Co and Pb on Soil, Montmorillonite and CaCO₃ under Effect of their Different Concentrations in Equilibrium Solution

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SORPTIVITY, as a reliable mechanism for reducing availability of heavy metal, was investigated on two soils, *i.e.*, Typic Torriorthent and Typic Haplocalcid, montmorillonite clay mineral and calcium carbonate. Three series of Cd, Co and Pb concentrations were equilibrated with each of the abovementioned adsorbents and the adsorption data were fitted to Langmuir, Van Bemmelen-Freundlich and Van-Huay adsorption isotherms. The results indicate that the studied isotherms could successfully describe the adsorption data. Maximum adsorption values calculated from Langmuir equation for Cd and Pb were lower in Typic Torriorthent soil than Typic Haplocalcid soil, whereas no obvious difference was detected for Co between the two investigated soils. Also, adsorption maxima for all the studied metal ions were found to be higher on montmorillonite clay mineral than on calcium carbonate. The binding energy values of the Typic Haplocalcid soil were higher than the corresponding ones of the Typic Torriorthent soil for both Co and Pb, while the opposite was true in case of Cd. Values of the binding energy for Cd, Co and Pb on CaCO₃ component seemed obviously higher than the corresponding ones on the montmorillonite clay mineral. Van-Huay equation showed that the Typic Haplocalcid soil affinity constants for Cd, Co and Pb were higher than the corresponding ones of the Typic Torriorthent soil. Although, the parameters calculated from Van Bemmelen-Freundlich equation have no certain indications, yet their positive values confirm the fitness of this equation to describe adsorption data of Cd, Co and Pb on the investigated adsorbents.

Keywords: Cd adsorption, Co adsorption, Pb adsorption, Montmorillonite, CaCO₃, Soil.

Heavy metals such as cadmium, cobalt and lead are toxic to higher plants and are considered one of the most environmental problems that facing mankind. To predict bioavailability, and hence potential toxicity and ultimately the impact of heavy metals on plants, it is imperative to understand metal- soil interactions at a fundamental level. The toxicity of heavy metals in ecosystems depends not only on the total metal concentration, but also more significantly on the soils ability to sorp metal ions from solid phase. Therefore, it is now generally accepted that sorption reactions on the surface of soil colloidal materials govern metal concentrations in the soil solution (Ismail, 2007). Also, one wants to minimize

the risk of heavy metals by leaching them deep into the soil and to limit uptake of contaminants by crops through immobilizing the metals. Clay minerals such as montmorillonite seem suitable as additives to immobilize heavy metals without affecting soil fertility negatively. Heavy metal cations are adsorbed on montmorillonite mainly by ion exchange, and so they can be readily exchanged for other cations such as calcium. The potential of montmorillonite to immobilize polluting heavy elements in agricultural soil was investigated by several investigators (Van Bladel *et al.*, 1993, Nasef, 1996, Badr, 2005, Ismail, 2007 and Abbas & Ismail, 2010).

Heavy metals in general and Cd, Co as well as Pb in particular can be introduced into soil and water environments from both natural (as reaction products via the dissolution of metal-bearing minerals) and anthropogenic (agricultural application of sewage sludge and fertilizers and / or through land disposal of metal-contaminated municipal and industrial wastes) sources (Wang and Xing, 2002, McNear *et al.*, 2005, Abbas, 2007 and Abbas & Ismail, 2010), however, metal inputs in soil can take several pathways depending on the soil ability to sorb or retain and store them according to the natural behavior of constituents as well as relative metals affinities for these surfaces to form strong complexes (Udeigwe *et al.*, 2011).

Adsorption is the net accumulation of matter at the interface between a solid phase and aqueous solution phase (Sposito, 2008). The relation between the amount of an element, a soil will absorb from a solution, and the concentration of this element left in the solution is known as the adsorption isotherms (Ismail, 2007). Adsorption isotherms show conveniently and quantitatively solute adsorption by solids at constant temperature and pressure. They show the amount of adsorbate (solute) sorbed as a function of its equilibrium concentration (Bohn *et al.*, 2001). Several adsorption equations are commonly used to describe adsorption data such as Langmuir, Freundlich and Van –Huay equations.

The Langmuir adsorption isotherm was firstly used for describing the adsorption of gases on solids (Langmuir, 1918) and has been used also to describe the relationship between the adsorption of ions by a solid and the concentration of the ion in solution (Ho *et al.*, 2004 and Li *et al.*, 2013).

Bohn *et al.* (2001) stated that the Langmuir equation is limited to the range of which experimental data are available. Extrapolation to higher concentrations predicts adsorption maximal often unsupported by the data. Even in systems where the energy of adsorption is not strictly constant, the Langmuir equation may still describe adsorption range, since the variation in energy of adsorption over a portion of adsorption over such a range should be small if only one type of binding site or mechanism predominates. Recently, workers have shown that precipitation reactions can also exhibit Langmuir-type behavior. If there is only a limited quantity in the system of another solute required to form the precipitate, a Langmuir isotherm can result with increasing concentrations of the solute in question, that is, a sorption maximum occurs. The key to this type of behavior is
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found at low concentrations of the solute in question, where no precipitation occurs until the solutes solubility product is increased (Bradl, 2004).

An advantage of using the Langmuir equation for describing adsorption is that it defines a limit to adsorption on a given array of sites that meet the Langmuir model criteria. This apparent limit has been used by many investigators to estimate the adsorption capacity of phosphate and herbicides. Comparing such capacities can also suggest adsorption mechanism (Rossi *et al.*, 2012).

The adsorption isotherm in many dilute solutions was formulated also by Freundlich (1926). Freundlich equation has no theoretical foundation and is empirical. The curve according to this equation is usually parabolic and exhibits the following characteristic features:

- There is no single point indicating that the process is completed.
- There is no region of discontinuity.

Another version of the Freundlich equation is called the Van Bemmelen-Freundlich equation (Sposito, 1980). This equation has often been associated with adsorption by heterogeneous surfaces.

Van-Huay (1975) suggested a linear equation for describing phosphate sorption by soils. Pagel *et al.* (1977) reported that Van-Huay equation has essential advantages over Langmuir isotherm in the lower range of P concentration, which is more important to plant growth. Nasef (1996) found that Van-Huay isotherm equation provided good fitness for Zn and Cu adsorption by calcareous soils varying widely in their contents of CaCO₃, as well as the clay minerals montmorillonite, attapulgite and kaolinite beside of pure CaCO₃.

Due to the abovementioned risks of heavy metals especially Cd, Co and Pb the current study was conducted to investigate the effect of soils as well as some of their components, *i.e.*, montmorillonite clay mineral and calcium carbonate as tools for minimizing concentrations of these metal ions in soil through sorption under different concentrations of applied Cd, Co and Pb.

Material and Methods

Material of study

Two surface soil samples (0-30 cm) varying in their chemical and physical properties were collected from the experimental farm, Faculty of Agriculture, Benha University, Qalubia Governorate and Nubaria Agricultural Research Station to represent non calcareous and calcareous soils, respectively. These soils are classified as Typic Torriorthent soil and Typic Haplocalcid soil, respectively. The soil samples were air dried, crushed, sieved through a 2 mm sieve then stored in air-tight jars. Also, montmorillonite clay mineral and calcium carbonate were selected as pure systems to study the adsorption reactions of Cd, Co and Pb.

The montmorillonite clay mineral used in this study was supplied by Sigma-Aldrich Chemical Company Inc. Its surface area is about $270 \text{ m}^2 \text{ g}^{-1}$ and its cation exchange capacity is $77.50 \text{ cmol}_c \text{ kg}^{-1}$. The laboratory reagent grade calcium carbonate used in this study was supplied by El-Gomhoria Company, Egypt. Some physical and chemical properties of the studied soils are shown in Table 1.

TABLE 1. Physical and chemical properties of the investigated soils.

Soil characteristic	Typic Torriorthent soil	Typic Haplocalcid soil
<i>Particle size distribution</i>		
Coarse sand %	2.27	16.22
Fine sand %	24.81	39.76
Silt %	22.27	25.95
Clay %	50.65	18.07
Textural class	Clay	Sandy clay loam
<i>Chemical analyses</i>		
Calcium carbonate (gkg^{-1})	14.3	248
Organic matter (gkg^{-1})	19.8	12.4
EC (dS m^{-1})*	1.69	3.30
pH(1:2.5) soil-water suspension	8.12	8.29
CEC $\text{cmol}_c \text{ kg}^{-1}$	35.21	11.20
<i>Soluble cations and anions ($\text{mmol}_c \text{ L}^{-1}$)*</i>		
Ca^{2+}	5.15	14.06
Mg^{2+}	3.20	5.03
Na^+	8.46	12.06
K^+	0.69	1.15
Cl^{-1}	7.00	10.00
HCO_3^{-}	2.04	2.90
CO_3^{2-}	0.00	0.00
SO_4^{2-}	8.46	19.40

* Soil paste extract.

Methods of soil analyses

Particle size distribution was conducted by pipette method using Na-hexametaphosphate as a dispersing agent as described by Klute (1986). Organic matter content was estimated by Walkley and Black method, total carbonates was determined using Collin's calcimeter, pH was determined electrometrically in 1:2.5 soil – water suspension using a pH meter, electrical conductivity of the soil paste extract was determined using electrical conductivity bridge and cationic and anionic composition of the soil paste extract was determined using the standard methods outlined by Page *et al.* (1982). Cation exchange capacity (CEC) was determined by displacing the exchangeable cations by BaCl_2 method as described by Lothenbach *et al.* (1997).

Adsorption experiments

The aim of these experiments was to study adsorption of Cd, Co and Pb by Typic Torriorthent soil and Typic Haplocalcid soil besides montmorillonite clay mineral and calcium carbonate. The applicability of the different isotherms for description of *Egypt. J. Soil Sci.* **53**, No. 2 (2013)

the adsorption data of the different materials was also concerned in this investigation. Sets of 50 mL glass bottles was used, each contained 1 g air dried soil (Typic Torriorthent soil or Typic Haplocalcid soil) or 0.1 g of montmorillonite clay mineral or calcium carbonate. Analytical reagent grade chemicals were used for preparing the trace metals stock solutions. Cadmium acetate $\text{Cd}(\text{CH}_3\text{-COO})_2 \cdot 2\text{H}_2\text{O}$, cobalt chloride $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$ and lead nitrate $\text{Pb}(\text{NO}_3)_2$ were used for preparing the stock solutions of Cd, Co and Pb at the concentration of 100 mg L^{-1} . The pH value of the solutions were adjusted at $7 (\pm 0.05)$ just before each adsorption experiment using 0.01 M NaOH or 0.01 M HCl. The prepared $\text{Cd}(\text{CH}_3\text{-COO})_2 \cdot 2\text{H}_2\text{O}$, $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$ or $\text{Pb}(\text{NO}_3)_2$ solutions were used to prepare a series of final Cd and Co concentrations, namely 0.75, 1.50, 3.00, 4.50 and 6.00 mg L^{-1} and Pb concentrations of 2.5, 5.0, 10.0, 15.0 and 20.0 mg L^{-1} . Twenty mL aliquot of either of the aforementioned prepared solutions was added to the soil, montmorillonite clay mineral or calcium carbonate contained glass bottle. Few drops of toluene were added to each bottle to prevent the growth of fungi, then the bottles were tightly closed, shaken for one hour. All bottles were left for equilibrium for 24hr, then centrifuged for 30 minutes at 5000 rpm, then the supernatants were obtained. Cadmium, cobalt or lead content in the supernatants (equilibrium solution) was determined, using ICP.MS. (Inductively Coupled Plasma Mass Spectrometer) TSA (POE.MS.111) and the amount of adsorbed ion on each adsorbent at the pH 7 was calculated as the difference between the Cd, Co or Pb initially added metal concentration and its concentration in the equilibrium solution.

Fitting Cd, Co and Pb sorption data to the different isotherm models

Three adsorption isotherm equations, *i.e.*, Langmuir, Van Bemmelen-Freundlich and Van-Huay were used to describe the equilibrium adsorption data. The convenient linear form of the Langmuir equation is expressed as:

$$1/q_e = 1/q^0 + [1/b q^0] [1/C_e] \quad \text{Eq. (1)}$$

(Al Duri, 1995)

Where:

- q_e : is the amount of solute adsorbed per unit weight of adsorbent (mg g^{-1}).
- C_e : is the equilibrium concentration of the solute (mg L^{-1}).
- q^0 and b : are Langmuir constants related to bonding energy and maximum adsorption, respectively.

The linear form of Van-Huay equation is:

$$Q = n\sqrt{I} + b_1 \quad \text{Eq. (2)}$$

(Van-Huay, 1975)

Where:

- Q = sorbed Cd, Co or Pb (mg kg^{-1} soil).
- I = concentration of Cd, Co or Pb in the equilibrium soil solution (mg L^{-1}).
- n = affinity constant of the adsorbed material to the adsorbate.
- b_1 = the intercept or theoretically the adsorbed amount of Cd, Co or Pb when $I = \text{zero}$ (mg L^{-1}).

The third adsorption isotherm used was Van Bemmelen-Freundlich (Sposito, 1980) which is well known as the Freundlich adsorption isotherm commonly used for describing the adsorption of trace metal cations at constant temperature by clay mineral and sesquioxides. The linear form of this equation is:

$$\text{Log } q_i = \text{log } \alpha + \beta \text{ log } C_i \quad \text{Eq. (3)}$$

Where:

q_i = is the amount adsorbed.

C_i = the concentration of trace metal cations in the aqueous solution.

α and β : are positive-valued adjustable parameters, with $0 < \beta < 1.0$.

These two parameters can be estimated by plotting $\text{log } q_i$ against $\text{log } C_i$ for the range of the adsorptive concentrations.

Results and Discussion

Sorption of Cd, Co and Pb on surfaces of the investigated adsorbents

Data illustrated graphically in Fig. 1, 2 and 3 show that increasing concentration of Cd, Co, or Pb in the equilibrium solution to any of the investigated adsorbents was associated by corresponding sorbed amounts of these ions on the surfaces of the studied adsorbents.

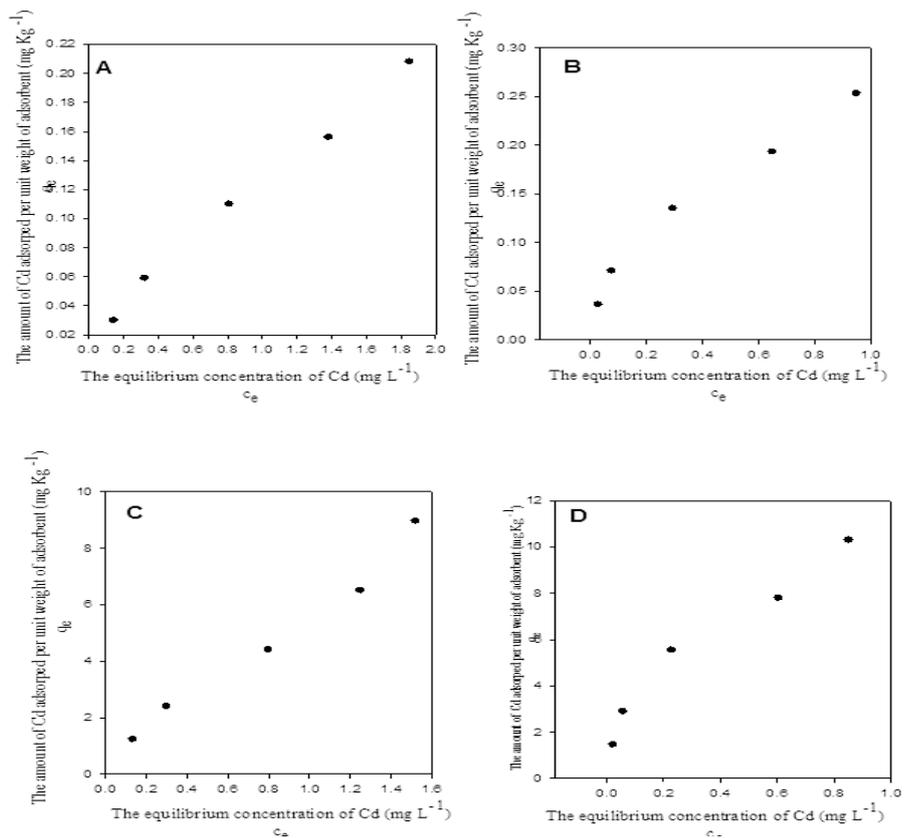


Fig. 1. Adsorption of Cd on Typic Torriorthent soil (A), Typic Haplocalcid soil (B), montmorillonite clay mineral (C) and CaCO_3 (D).

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Sorption of the studied metal ions might occur on the colloidal (clay and organic matter) fractions of the soils as well as the calcium carbonate present in these soils. Clays and organic matter adsorb metal ions quite strongly (Iskrenova-Tchoukova 2010 and Moghal & Al-Shamrani, 2012). Nasef (1996) concluded that both the clay fraction and the organic matter contents could be considered among the main factors responsible for increasing amount of the adsorbed metal ions or in another meaning reducing concentrations of these ions in equilibrium solution. Shaheen (2009) reported that sorption parameters were correlated to clay content, cation exchange capacity and organic matter content. However, no one can deny the contribution of the CaCO_3 content of soil to reduction of the metal ions in equilibrium solution and consequently increasing amounts of the metal ions sorbed on soil.

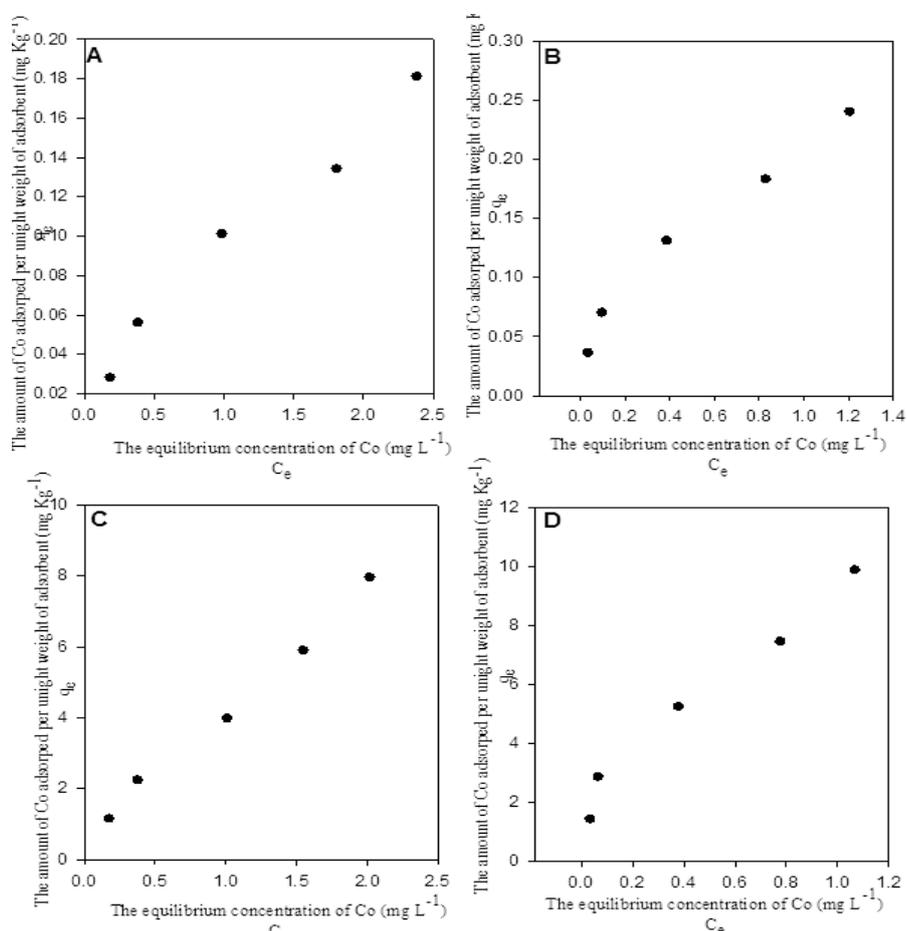


Fig. 2. Adsorption of Co on Typic Torriorthent soil (A Typic Haplocalcid soil (B), montmorillonite clay mineral (C) and CaCO_3 (D).

Figures 1, 2 and 3 reveal also that Typic Haplocalcid soil showed ability to retain higher amounts of metal ions than Typic Torriorthent soil one. This occurred in spite of the higher clay and organic matter contents of the later soil than the former one. Such a finding might be, therefore, attributed to the higher CaCO_3 of Typic Haplocalcid soil. Hence, the comparison between the clay and organic matter contents on one hand and the CaCO_3 content on the other one might indicate that CaCO_3 is probably of more obvious ability to render metal ions insoluble or in other words sorbed on soil surface. This conclusion stands in well agreement with those of Abd El-Hamid *et al.* (1996) on Cd, Ni and Pb and Ismail (2007) on Ni and Co.

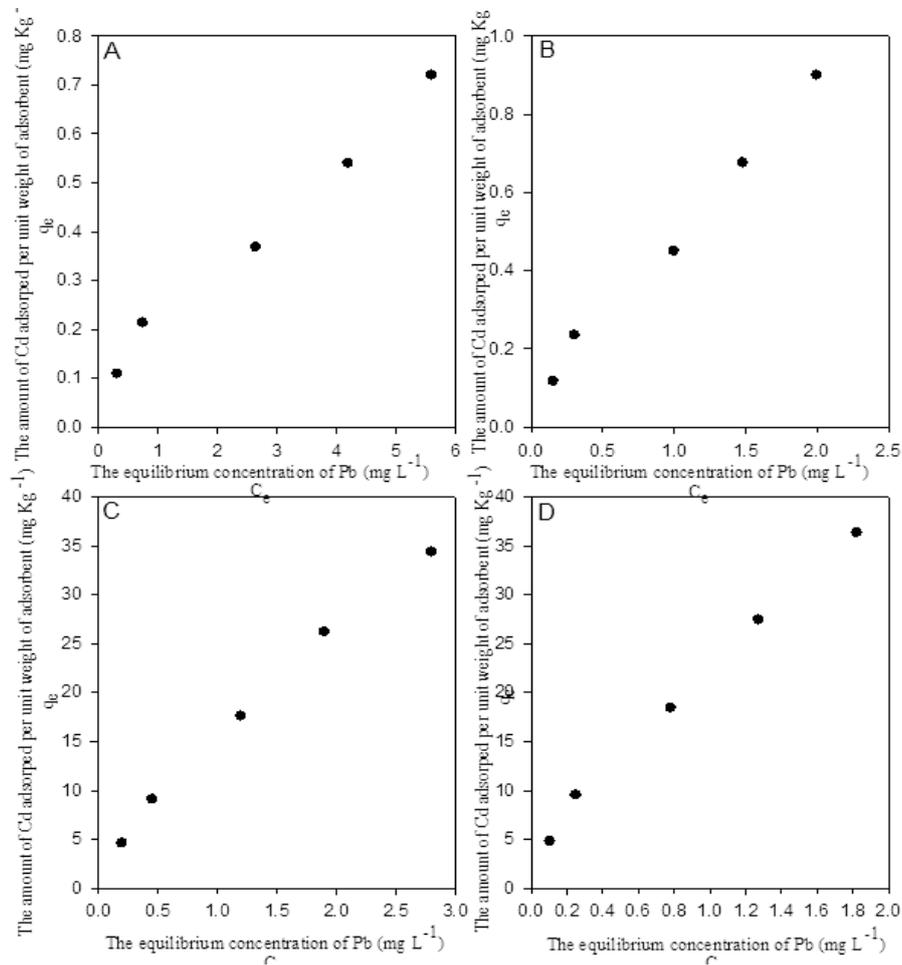


Fig. 3. Adsorption of Pb on Typic Torriorthent soil (A), Typic Haplocalcid soil (B), montmorillonite clay mineral (C) and CaCO_3 (D).

Sorption isotherm curves

The sorption parameters calculated from the different sorption isotherms of the studied soils, montmorillonite clay mineral and calcium carbonate component are presented in Tables 2-4.

Langmuir sorption isotherm

The data obtained for Cd, Co and Pb adsorption by the studied soils as well as the montmorillonite clay mineral and calcium carbonate component were arranged to be used for plotting the Langmuir adsorption isotherm in the linear form.

The amounts of Cd, Co and Pb in the equilibrium solutions of the investigated adsorbents (C_e) were found to be correlated at a high level of significance with C_e/q_e values. This means that adsorption of Cd, Co and Pb on both the studied soils as well as the montmorillonite clay mineral and calcium carbonate component obeyed Langmuir equation. These results agree well with those of Badr (2005) and Ismail (2007).

TABLE 2. Different parameters of adsorption isotherms of Cd for the studied adsorbents.

Adsorbent	Langmuir isotherm			Van-Huay isotherm			Van Bemmelen-Freundlich isotherm		
	"q ₀ "	"b"	r ²	"n"	"b ₁ "	r ²	"α"	"β"	r ²
Typic Torriorthent soil	0.527	0.395	0.925	0.175	-0.041	0.988	0.129	0.738	0.997
Typic Haplocalcid soil	0.131	2.985	0.967	0.257	-0.005	0.995	3.357	0.254	0.995
Montmorillonite	0.446	19.570	0.712	8.231	-2.149	0.949	5.797	0.773	0.989
CaCO ₃	4.908	11.710	0.959	10.685	0.097	0.9869	11.033	0.511	0.986

"q₀" Binding energy.

"b" Maximum adsorption,

"n" Affinity constant of the adsorbed ion to the adsorbate ,

"b₁" the theoretically adsorbed amounts of Cd, Co or Pb when its concentration in the equilibrium solution I = zero mgL⁻¹,

"α" and "β" are positive-valued adjustable parameters, with 0 < β < 1.0.

TABLE 3. Different parameters of adsorption isotherms of Co for the studied adsorbents.

Adsorbent	Langmuir isotherm			Van-Huay isotherm			Van Bemmelen-Freundlich isotherm		
	"q ⁰ "	"b"	r ²	"n"	"b ₁ "	r ²	"α"	"β"	r ²
Typic Torriorthent soil	0.549	0.297	0.930	0.129	-0.027	0.984	0.097	0.649	0.987
Typic Haplocalcid soil	2.933	0.285	0.951	0.214	-0.003	0.994	0.213	0.519	0.995
Montmorillonite	0.384	16.584	0.781	6.430	-1.816	0.966	4.342	0.757	0.992
CaCO ₃	3.506	11.274	0.922	9.034	-0.013	0.978	9.014	0.504	0.967

See footnote of Table 2.

TABLE 4. Different parameters of adsorption isotherms of Pb for the studied adsorbents.

Adsorbent	Langmuir isotherm			Van-Huay isotherm			Van Bemmelen-Freundlich isotherm		
	"q ₀ "	"b"	r ²	"n"	"b ₁ "	r ²	"α"	"β"	r ²
Typic Torriorthent soil	0.308	1.017	0.849	0.316	-0.083	0.966	0.228	0.619	0.984
Typic Haplocalcid soil	0.433	1.782	0.787	0.725	-0.188	0.969	0.506	0.752	0.987
Montmorillonite	0.327	69.444	0.927	24.247	-7.174	0.992	15.849	0.757	0.999
CaCO ₃	0.716	60.241	0.905	30.018	-5.831	0.986	23.302	0.692	0.997

See footnote of Table 2.

Maximum adsorption (b)

The values obtained for the maximum adsorption of Cd, Co and Pb on the investigated adsorbents are presented in Tables 2-4. Values of the maximum adsorption (b) of the Typic Torriorthent soil for Cd and Pb were lower than the corresponding ones of the Typic Haplocalcid soil, however values of the maximum adsorption of the Typic Torriorthent soil and Typic Haplocalcid soil for Co seemed closely related to each other. These results probably indicate that the Typic Haplocalcid soil is generally characterized by higher adsorption maxima for metal ions than the Typic Torriorthent soil. Adsorption maxima for all the studied metal ions were found to be higher on montmorillonite clay mineral than on calcium carbonate. This finding is probably owing to the higher cation exchange capacity of the montmorillonite clay mineral.

The binding energy (q₀)

Data presented in Tables 2-4 show values of the binding energy (q₀) of the investigated soils for Cd, Co and Pb as calculated from the linear form of Langmuir equation. According to these values, it can be noticed that the Typic Haplocalcid soil showed higher binding energy for Co and Pb than the Typic Torriorthent soil. On the other hand, the Typic Torriorthent soil showed lower binding energy for Cd than the Typic Torriorthent soil. The difference in the binding energy between the two studied soils may suggest the presence of more than components and consequently more than mechanism by which the metal ions are retained to the soils. This means that the interaction among the different soil components may result in different effects on values of binding energy of the soil to the metal ion dependent on nature of soil components, its percentage and reactivity with the metal ions (Violante *et al.*, 2010). Values of the binding energy for Cd, Co and Pb on CaCO₃ component seemed obviously higher than the corresponding ones on the montmorillonite clay mineral giving reason for the observed higher values of binding energy of the Typic Haplocalcid soil for Co and Pb metal ions than the Typic Torriorthent soil.

Van-Huay sorption isotherm

Tables 2-4 reveal that sorption data for the Typic Haplocalcid soil and Typic Torriorthent soil investigated soils as well as the montmorillonite clay mineral and CaCO₃ adsorbents fitted to the linear form of Van-Huay equation at a high

level of significance indicating a good adherence of the data to Van-Huay adsorption model.

The affinity constant "n"

The affinity constant "n" of the adsorbed metal ion on the adsorbates could be calculated from the linear form of Van-Huay equation, $Q = n\sqrt{I} + b$ as the slope of this equation.

Data presented in Tables 2-4 show that values of this parameter were 0.157 and 0.257, 0.129 and 0.214 and 0.316 and 0.725 for Cd, Co and Pb on the Typic Torriorthent soil and Typic Haplocalcid soil, respectively. It is noticeable also that the Typic Haplocalcid soil affinity constants for Cd, Co and Pb were higher than the corresponding ones of the Typic Torriorthent soil. Consequently, it might be deduced that affinity of soil to adsorb Cd, Co or Pb is likely to be dependent, among several factors, on its content of CaCO_3 . However, it must be taken into consideration that some other factors such as the clay content, its type as well as the organic matter content might contribute also to determine the affinity of element to any metal ion. This conclusion stands in well agreement with the results of Nasef (1996) on Zn and Cu, Badr (2005) and Ismail (2007) on Ni and Co.

Thus, values of the constant "n" referring to the affinity of an element to the soil could be considered a final product of interaction effect among these factors.

Data presented in the aforementioned tables reveal that values of affinity constant "n" calculated according to Van-Huay isotherm of the montmorillonite clay mineral for all the studied metal ions, *i.e.*, Cd, Co and Pb were obviously lower than the corresponding ones of the CaCO_3 . This finding confirms the abovementioned results which declared the higher affinity constant of the higher CaCO_3 contained soil, *i.e.*, the Typic Haplocalcid soil one.

The constant "b₁"

The theoretical adsorbed amount of element (constant "b₁") is calculated as the intercept of the linear form of Van-Huay equation. The values obtained for this constant "b" are presented in Tables 2-4. It is obvious that values of this parameter are generally negative which may be explained by the fact that at a concentration of zero mg L^{-1} of an ion in equilibrium solution, it is not expected for this ion to be adsorbed on the adsorbent, on the other hand, a portion of this ion might adsorbed and releases into the equilibrium solution. Thus, it can be deduced that at zero concentration of an ion, desorption of this ion from the adsorbents would be the prevailing reaction, and hence it might be suggested to indicated to the constant b₁ in Van-Huay equation as theoretical desorbed amount of the element instead of the theoretical adsorbed amount.

Van Bemmelen-Freundlich sorption isotherm

Data presented in Tables 2-4 and illustrated graphically in Fig. 1, 2 and 3 were used for plotting values of $\log C_e$ against the corresponding ones of $\log q_e$.

The regression equations representing the relation between these two variables as well as values of correlation coefficient between them are presented in Tables 2-4. The obtained "r" values indicate that these results fitted at a high level of significance the Van Bemmelen-Freundlich equation.

All " β " values were in the range $0 < \beta < 1.0$ which coincides with the results obtained by many investigators such as Sposito (1980) and Nasef (1996). However, these values seemed to be higher for Cd and Co in cases of Typic Torriorthent soil and the montmorillonite clay mineral than in cases of Typic Haplocalcid soil and CaCO_3 as well. On the other hand, Pb showed a contradictory trend.

It is obvious that the constant " α " ranged from 0.1287 to 11.0332 in case of Cd. The corresponding " α " values ranged from 0.0971 to 9.0136 in case of Co while those in case of Pb ranged from 0.228 to 23.3024. No indications are known for the parameters α and β but their positive values which confirm the suitability of Van Bemmelen-Freundlich equation for describing adsorption data of Cd, Co and Pb on the used adsorbents.

Conclusion

The results indicated that adsorption is the principle mechanism responsible for Cd, Pb and Co retention in Typic Torriorthent and Typic Haplocalcid soils, montmorillonite clay mineral and calcium carbonate. The sorption data could successfully be described by the adsorption isotherm models, *i.e.*, Langmuir, Van-Huay and Van Bemmelen-Freundlich with high fitness.

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إدمصاص وترسيب الكاديوم والكوبلت والرصاص على الأرض وطين المونتموريلونيت وكربونات الكالسيوم تحت تأثير تركيزات مختلفة منهم في محلول الإتزان

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يعتبر الإدمصاص والترسيب ميكانيكية يمكن الإعتماد عليها في إختزال نيسر العناصر الثقيلة في التربة وتعتمد هذه الميكانيكية على تأثير مكونات التربة المختلفة في تقييد الأيونات المعدنية في التربة وتحويلها إلى صورة صعبة الإمتصاص بواسطة النباتات المنماة في التربة.

أجريت تجارب إدمصاص على نوعين من التربة إحداهما غيرجيرية Typic Torriorthent والأخرى جيرية Haplocalcid Typic بالإضافة إلى معدن طين المونتموريلونيت وكذلك كربونات الكالسيوم حيث أضيف الكاديوم أو الكوبلت أو الرصاص بتركيزات مختلفة إلى أى من مواد الإدمصاص موضع الدراسة ثم الرج والطرذ المركزى وتقدير كل من الكاديوم والكوبلت والرصاص في الرائق وتم حساب الكمية المدمصة لعناصر الدراسة. وقد نجحت معادلات الإدمصاص التالية (لانجمير - فان فرويند لخ - فان هوى) في وصف نتائج تجارب الإدمصاص. وقد أبدت الأرض الجيرية Haplocalcid Typic مقدرة أعلى على إدمصاص الأيونات موضع الدراسة عن الأرض الغير جيرية Torriorthent Typic وبالمثل أبدت كربونات الكالسيوم كفاءة أعلى عن معدن طين المونتموريلونيت في جعل هذه الأيونات غير ذائبة. وقد أوضحت النتائج أن قيم أقصى إدمصاص (كما تم حسابها من معادلة لانجمير) للأرض الغير جيرية لكل من عنصرى الكاديوم والرصاص كانت أقل من القيم المقابلة للأرض الجيرية، في حين أنه لم يتضح هناك فرق محسوس بين قيم أقصى إدمصاص للأراضى موضع الدراسة لعنصر الكوبلت. أيضاً فإن قيمة طاقة الإدمصاص للأرض الجيرية والتي تم حسابها من معادلة الإدمصاص سالفة الذكر كانت أعلى من القيم المقابلة لها في حالة الأرض الغير جيرية لكل من عنصرى الكوبلت والرصاص بينما كان العكس صحيحاً في حالة عنصر الكاديوم.

أوضحت معادلة فان هوى أن معامل أفضلية الأرض الجيرية Typic Haplocalcid لعناصر الدراسة الكاديوم والكوبلت والرصاص كانت أعلى من القيم المقابلة للأرض الغير جيرية Torriorthent Typic. وبالرغم من أن المعايير التي تم حسابها من معادلة فان فرويند لخ ليست لها دلالات خاصة إلا أن قيمها الموجبة تؤكد ملائمة هذه المعادلة لوصف بيانات عملية الإدمصاص لعناصر الدراسة الكاديوم والكوبلت والرصاص على مواد الإدمصاص سالفة الذكر (موضع الدراسة).