

Sorption of Pb and B on Soils and their Separated Clay Fractions

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ABSTRACT

Pollution is one of the main threats possessing a potential risk for man and animals, especially the potentially toxic elements (PTE) which are considered non-biodegradable and can persist in soils for years. Clay minerals are thought to be among the main factors immobilizing PTE in soils and; therefore, these minerals control their bioaccessibility. Thus, the current research aims at determining the mechanisms by which the potentially toxic element Pb beside of the metalloid B are retained in a clayey non-calcareous soil and a clayey calcareous one under different pH values i.e. 5, 7 and 9. The clayey non-calcareous soil is characterized by a clay content of 58.25% and CaCO₃ content of 24.8 g kg⁻¹ while the clayey calcareous one is characterized mainly by a clay content of 40.75% and CaCO₃ content of 289.9 g kg⁻¹. The clay fraction of the investigated soils was separated and identified of the types of the clay minerals dominating in these soils using X-ray diffraction analyses. Montmorillonite was the dominant clay mineral in the non-calcareous clayey soil, whereas kaolinite and palyorskite were the dominant ones in the calcareous clayey one. Adsorption of Pb and B on soils and clay minerals increased gradually with increasing the initial concentration of these ions in the equilibrium systems, especially with increasing the pH of these systems from 5 to 9. In this concern, adsorption of the investigated ions by the clay minerals exhibited much higher values than those occurred on the investigated soils. Freundlich isotherm was the most efficient model fitting Pb sorption on both soils and clay minerals, whereas, Langmuir isotherm model seemed to be more appropriate for fitting the sorption data of B on the investigated soils and separated clay minerals. In conclusion, adsorption of Pb and B on clay minerals seemed to be the dominant mechanism controlling their mobility in soils even at pH 9. The actual sorption capacities and affinities in soils remained much lower than that occurred by the separated clay minerals. To what extent can clay minerals retain PTE versus a clayey and a calcareous clayey soils was a matter of concern in this study.

Keywords: lead; boron; sorption, pH; Freundlich; Langmuir; clay minerals; calcareous and non-calcareous soils

INTRODUCTION

Pollution is one of the main threats possessing a potential risk for man and animals (Abdelhafez *et al.*, 2015; Hashem *et al.*, 2017; Cachada *et al.*, 2018; Alshaal *et al.*, 2019), especially the PTE which are considered non-biodegradable materials and can persist in soils for years (Adamo *et al.*, 2018). Thus, studying factors affecting their solubility and availability in soils might highlight the appropriate methods for amelioration of contaminated soils or waters (Rodrigues and Römken, 2018) to attain more acceptable environmental conditions (Xu *et al.*, 2017; Abbas and Bassouny, 2018).

Sorption/desorption reactions are thought to be among the main factors affecting the availability and phytotoxicity of PTE (Abbas and Salem, 2011; Violante *et al.*, 2010). In this concern, clay minerals can probably immobilize PTE (Singh *et al.*, 2006; Xu and McKay, 2017) because of their large surface area and the negative charge that exists on their fine particles (Xu and McKay, 2017), thus clay minerals control their bioaccessibility in soils (Abbas and Ismail, 2010) and water (Churchman *et al.*, 2006) e.g. kaolinite and montmorillonite (Bhattacharyya and Gupta, 2008). These materials are cheap and therefore used successfully to decrease the solubility of PTE in wastewater (Uddin, 2017). Even in soils, clay minerals e.g. montmorillonite linings are widely used to landfill the bottoms in order to avoid further transfer of the contaminant to the sub soils and groundwater (Barbier *et al.*, 2000).

Sorption of Pb(II) on the montmorillonite clay mineral may take place through ion exchange and precipitation on the surface (Abdellaoui *et al.*, 2017) and, in case of kaolinite clay mineral, Pb sorption might exist as a result of ion exchange and surface complexation, beside of the protonation–deprotonation reactions of the surface sites (Mascia *et al.*, 2015). In spite of that data of sorption of Pb on kaolinite and montmorillonite fitted the Langmuir

monolayer model (Xu and McKay, 2017). Thus, adsorption of Pb on clay minerals and probably on soils is still not well defined. On the other hand, H⁺ ions can compete with PTE on sites of sorption at pH <4 while sorption on clay montmorillonite takes place at pH (4–6); afterwards, precipitation seemed to be the dominant process (Altin *et al.*, 1999). Thus, following the sorption of PTE under different pH levels was another target in this study

Boron is an essential nutrient for plants, however, its toxicity appears at high concentrations in soils and water (Theiss *et al.*, 2013) threatens the health of organisms in the ecosystems (Jalali *et al.*, 2016). Accordingly, ameliorating waters polluted with boron should be considered to match the environmental restrictions (Tagliabue *et al.*, 2014). In this concern, B is a strong electron acceptor which is found in coordination III (H₃BO₃) or IV (B(OH)₄) (Gaillardet and Lemarchand, 2018). In spite of being an anion, chemisorption characterizes its sorption on soils (Sá and Ernani, 2016) especially with increasing the clay content in soils (Debure, *et al.*, 2018) and/or increasing soil pH (Goldberg and Suarez, 2017).

The current research aims at determining the sorption mechanisms of Pb and B on both kaolinite and montmorillonite clay minerals in a trial to evaluate the efficiency of these clay minerals to immobilize the contamination level of these cations (Pb) and anions (B) under different pH values i.e. 5, 7 and 9. Sorption of these cations and anions were also considered on clayey non-calcareous and calcareous soils for data comparison.

MATERIALS AND METHODS

Materials of study

Surface soil samples, differing mainly in their contents of CaCO₃, were collected from two sites different soils i.e. Moshtohor (Toukh, Qualubia Governorate) to represent the clayey non-calcareous soil and El- Nubarya

(El-Behira Governorate) to represent the clayey calcareous one. Soil samples were analyzed for their chemical properties as well as their particle size distribution as

outlined by Klute (1986) and Sparks *et al.* (1996) and the results are presented in Table 1.

Table 1. Chemical characteristics and particle size distribution of the collected soil samples

	pH*	EC** ₁ dS m ⁻¹	OM ₁ , g kg ⁻¹	CaCO ₃ g kg ⁻¹	Particle size distribution, %				Soil texture	Pb mg kg ⁻¹	B mg kg ⁻¹
					Coarse sand	Fine sand	Silt	Clay			
Moshtohor	7.93	1.89	25.7	24.8	6.78	6.81	28.16	58.25	Clayey	101.35	47.90
El- Nubarria	8.21	3.39	14.3	289.9	24.57	24.21	10.47	40.75	Sandy Clay	41.36	51.20

Separation of the clay fraction

Separation of clay fractions from the investigated soils were carried out according to the method outlined by Jackson (1969) i.e. (1) removal of calcium carbonate by “sodium acetate + acetic acid (pH 5, 1N)” buffer solution, (2) removal of the organic matter and magnesium oxides by 30% hydrogen peroxide, (3) removal of free iron oxides by a mixture of Na-citrate +bicarbonate-dithionite. Samples were then diluted with deionized water and treated with sodium hydroxide solution (pH 9.5) for dispersing the colloidal system. After sedimentation of the large particles, the fine clay fractions (diameter <2 u m) were collected.

Mineralogical analysis of the clay fraction

X-ray diffraction analysis was carried out on the clay fractions from the previous step using Phillips PW 1140/90 X-ray apparatus, with nickel filter and Cu-radiation. Oriented clay samples were prepared on glass slides as follows: Mg- saturated air-dried samples, Mg-saturated glycerol solvated ones, K-saturated air dried samples and K-saturated ones which were subjected to 550° C for 4 hours.

Interpretation of the x-ray diffraction patterns was based on the presence of diffraction peaks characterizing the crystalline societies present in samples. The diagnostic criteria used for identification of the clay and accessory minerals were reported by Brown (1961), Patterson (1963), Jackson (1969) and El-Attar and Jackson (1973) as follows:

- (1) Smectite (montmorillonite) exhibits a basal reflection (001) at about 14.0-14.5 A° for Mg-saturated sample which expands at 17.8 A° upon glycerol solvation and then collapse further to 10.0 A° after heating at 550° C for four hours.
- (2) Kaolinite gives a strong spacing at 7.13 A° and 3.57 A° in the Mg-saturated samples which remain unchangeable in the other treatments and disappear upon heating at 550° C for four hours.
- (3) Hydrous mica (Illite) gives a diffraction peak at 9.96-10.28 A° in the Mg-saturated sample while remains constant in the other treatment.
- (4) Palygorskite is distinguished by the spacing of 10.40-10.53A°, 6.4-6.48 A°, 4.45-4.55 A°, 3.2-3.25 A° and 2.56-2.58 A° in all treatments.
- (5) Interstratified clay minerals are characterized by the presence of small peaks around 20 A° in the air-dried sample, it is evidenced also by tailing of the 10 A° towards the 14A° and 19 A° peaks.
- (6) Quartz gives basal reflection at 3.33 and 3.42 A° and 4.26 – 4.43 A° peaks.

- (7) Feldspars and calcite are identified by their characteristic diffraction peaks at 3.1-3.25 A° and 3.03 A°, respectively.

The Sorption study

Stock solutions of Pb and B were prepared from lead (II) nitrate in nitric acid 0.5 M (1000 Pb mg L⁻¹, Schrlau Chemicals) and. One thousand mg B L⁻¹ was prepared from H₃BO₃ (Alpha Chemika, FW: 61.83 AR) , respectively These solutions were subjected to a series of dilutions to set the following standard ones: 0 -80 mg Pb L⁻¹ and 0-50 mg B L⁻¹. Soil portions equivalent to 2.5 g were placed into 50mL centrifuge reaction tubes together with either of the standard solutions (20 mL, each) and then shaken for 30 min. Afterwards, suspensions were centrifuged at 3000 rpm and then filtered using Whatman filter paper No. 42. In case of the separated clay fractions, clay suspensions were prepared with the standard solutions at a ratio of 1:200. These suspensions were shaken for 30 min., centrifuged and filtered to get the supernatants.

Chemical analyses

Portions of the investigated soils and clay minerals were digested in aqua regia as outlined by Abbas and Abdelhafez (2013) to determine their total contents of Pb and B. Total contents of Pb and B in the supernatants and soil digests were determined using ICP Optical Emission Spectroscopy ULTIMA 2 (Limit of detection 1.1 mg L⁻¹ for Pb and 0.3 mg L⁻¹ for B).

Data processing

Sorbed PTE were calculated by subtracting the equilibrium concentrations from the initial ones. Relations between the sorbed amounts of PTE per unit volume of soil versus the equilibrium concentrations were plotted graphically and fitted to the different adsorption isotherm models as described by Loffredo and Senesi (2006) and Sposito (2008).

$$\text{Linear model } Q=k_p C \tag{Eq. 1}$$

$$\text{Langmuir isotherm } Q = \frac{abC}{1 + bC} \tag{Eq. 2}$$

$$\text{Van Bemmelen- Freundlich } Q = kC^{\frac{1}{n}} \tag{Eq. 3}$$

Where

Q_e is the amount of sorbed PTE at the equilibrium, C_e is the concentration of PTE at equilibrium, k and n are constants, the parameters “a” and “b” refers to the capacity and affinity coefficients, respectively.

RESULTS AND DISCUSSION

X-ray analysis

X-ray diffraction patterns of the clay fractions separated from Moshtohor and El-Noubaria are shown in Figs. 1 and 2.

A semi quantitative estimation of the clay minerals is interpreted by measuring the peak area as outlined by *Brown (1961)* and the results are presented in Table 2. Data reveal that the dominant clay mineral in Moshtohor soil is

semectitie (montmorillonite) followed by kaolinite. The accessory minerals are dominated by quartz followed by feldspar while calcite was found as traces. In case of El-Nobariya separated clay fraction, interpretation of the x-ray differactograms revealed that kaolinite was the dominant clay mineral with less pronounced occurrence of polygorskite minerals. Interstratified minerals are detected in trace amounts. They are mainly dominated by quartz followed by feldspars.

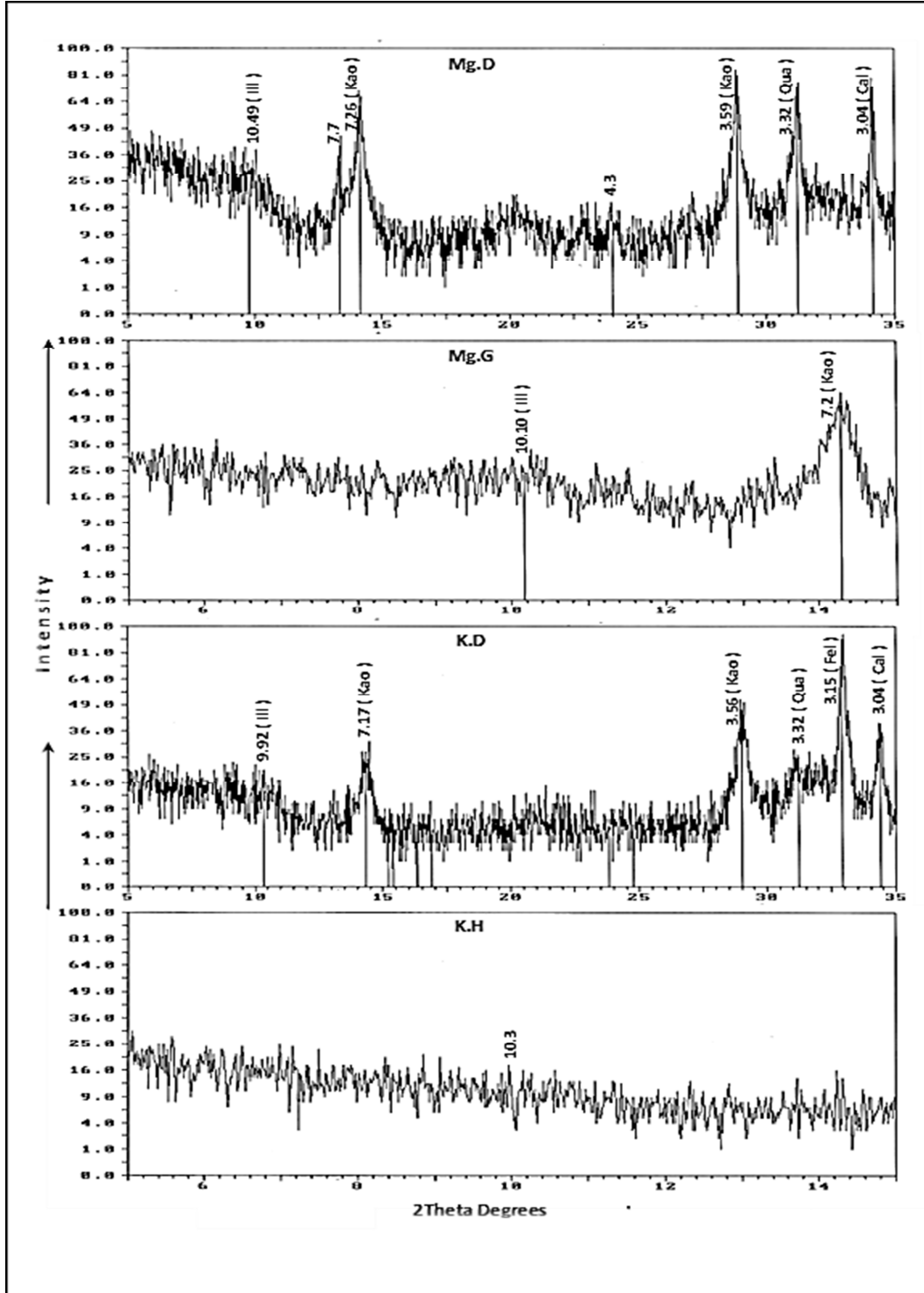


Fig. 1. X-ray diffraction patterns of the clay fraction separated from Moshtohor soil (Mg.D: Mg air dry, Mg.G: Mg glycerolated, K.D: K air dry, K.H : K Heated)

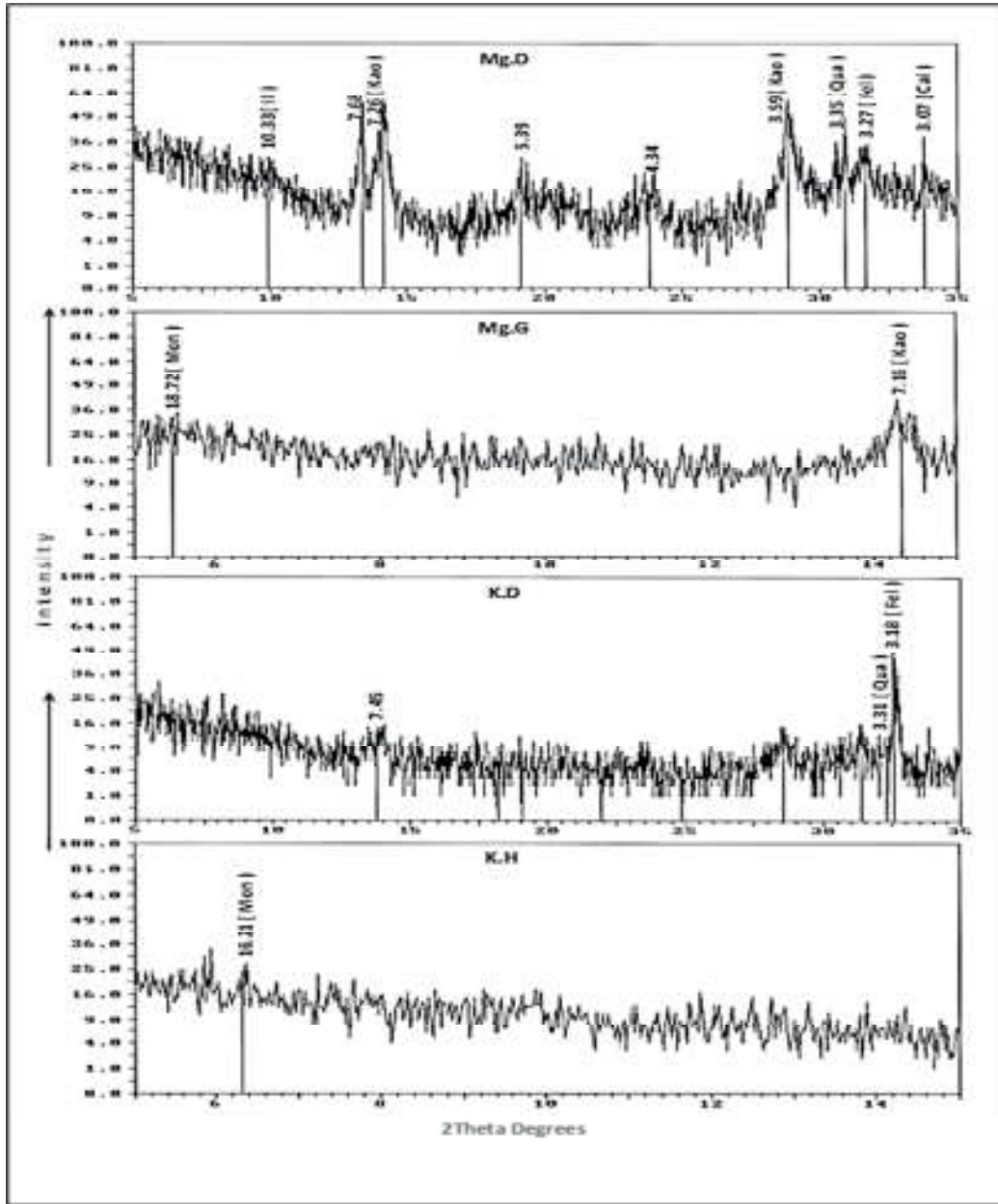


Fig. 2. X-ray diffraction patterns of the clay fraction separated from El-Nobariya soil (Mg.D: Mg air dry, Mg.G: Mg glycerolated, K.D: air dry, K.H : K Heated)

Table 2. Semi-quantitative analysis of the clay fraction separated from the studied soil samples

Type	Clayey non-calcareous soil	Clayey calcareous soil
Interstratified Smectite (Mont.)	-	Tra
Chlorite	-	-
Vermiculite	-	-
Kaolinite	Mod	Com
Illite	-	-
Paligorskite	-	-
Quartz	Tra	-
Feldspars	Tra	Tra
Calcite	Tra	Tra
Dolomite	-	-
Apatite	-	-

Tra: Trace, Few: 5-15%, Mod: (15-25%) Moderate, Com.: (25-40%) common, Dom. :>40%) Dominaute

Lead (Pb) sorption on soils and their separated clay fractions.

Effect of the initial Pb concentrations and pH values on Pb sorption on soils and clay minerals.

Sorption of Pb on soils and the clay fractions separated from these soils increased gradually with increasing the initial concentration of Pb in the metal-clay system (Fig. 3). In this concern, the sorption of Pb from the aqueous solution by the clay fraction was 10 fold higher than that occurred on the investigated soils. Such a sorption process is thought to be spontaneous and exothermic (Taha et al., 2016). It seems that the pH value of the equilibrium systems was another factor affecting Pb-sorption on the clay fractions and, to a lower extent, on soils. Generally, Pb sorption decreased on soils and the separated clay fractions with decreasing the pH value. These results agree with those of Zhang and Hou (2008). This might take place

because decreasing the pH of the suspension resulted in concurrent reductions in the pH dependent charge located at the broken edges of the clay minerals (Chen *et al.*, 2009). Moreover, competition between H⁺ and the potentially toxic element occurred under acidic conditions, thus sorption of Pb seemed to be lower on soils and clay minerals (liu *et al.*, 2016). Although, sorption of Pb was

higher on the clay fraction separated from the non-calcareous soil than that existed on the clay fraction separated from the calcareous one at both pH 5 and 7; however, this sorption varied slightly between these two clay fractions at pH 9. Probably, increasing pH favors further precipitation of Pb in the form of insoluble hydroxides (Gupta and Bhattacharyya, 2008).

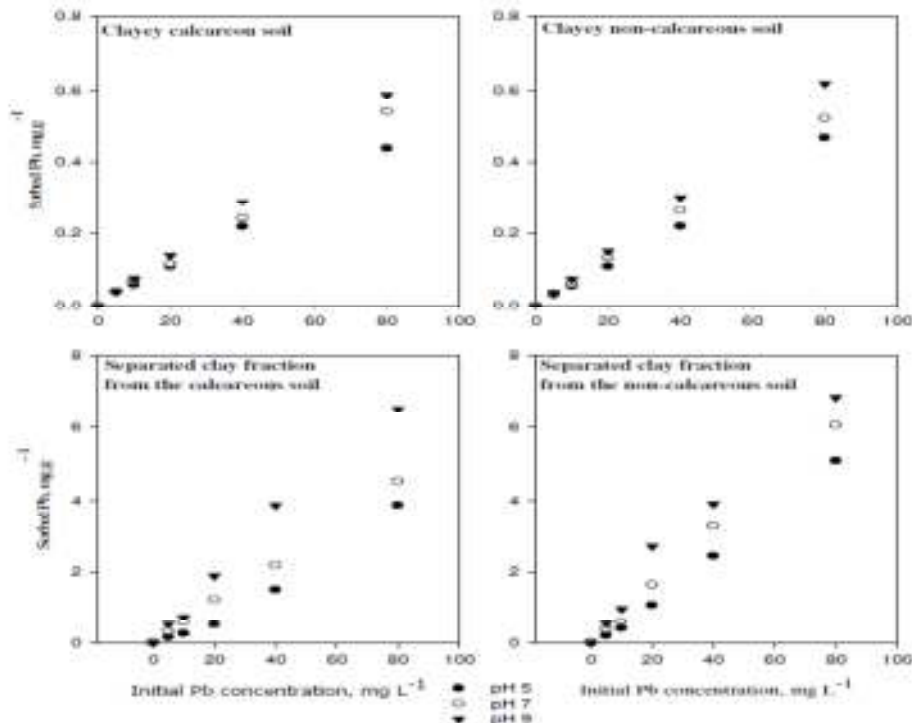


Fig. 3. Sorption of Pb on soils and the separated clay fractions as affected by the initial concentrations of the applied Pb under different pH values.

Sorption of Pb on soils and the separated clay fractions as affected by Pb concentration in the equilibrium concentration

Sorbed Pb versus the equilibrium concentration (Fig. 4) was fitted to three adsorption isotherm models i.e. Langmuir, Freundlich and the linear models. The parameters calculated from these models are presented in Table 3. According to the highest “r²” values, both of the Langmuir and Freundlich isotherms were the most efficient models fitting Pb sorption on soils and the separated clay fractions. These results agree, to some extent, with those of both Gupta and Bhattacharyya (2005) and Jiang *et al.* (2009). On the other hand, the “b” parameter (calculated from the Langmuir isotherm model) recorded negative values at pH 5 and for different soils and separated fractions equilibrium systems. Similar behavior was detected both at the non-calcareous and the calcareous soils at pH 9 and the calcareous soil at pH 7 whereas the “b” value was positive in case of the other metal-soils (or their separated clay fractions) equilibrium systems. Accordingly, Langmuir model seemed to be inappropriate for describing Pb sorption on soils and the clay fractions and therefore, the Freundlich model was the most efficient model fitting sorption data. These findings agree with the results of Adebowale *et al.* (2006) and Jiang *et al.* (2010) who found that Pb sorption on kaolinite was the most efficient fitted by Freundlich rather than Langmuir equation. In case of the clay fraction separated from the non-calcareous soil,

two binding sites were assumed for the sorption of Pb on the clay surfaces i.e. ion exchange and surface complexation (Barbier *et al.*, 2000). However, the obtained values seemed to be much lower than those detected by Gupta and Bhattacharyya (2008) which were within the range of 6.8–11.5 mg g⁻¹ for the kaolinite mineral and 21.1–31.1 mg g⁻¹ the montmorillonite clay.

Table 3. Calculated parameters and “r²” values for the adsorption isotherm models of Pb on soils and clay minerals

	linear isotherm		Langmuir isotherm			Freundlich isotherm		
	Kp	r ²	a	b	r ²	x	1/n	R ²
The non-calcareous soil								
pH=5	0.047	0.691	0.450	-0.044	0.966	0.018	0.977	0.988
pH=7	0.034	0.870	0.214	-0.056	0.975	0.014	2.323	0.952
pH=9	0.082	0.945	0.761	-0.067	0.981	0.038	1.460	0.977
The calcareous soil								
pH=5	0.021	0.983	1.000	-0.015	0.997	0.011	1.255	0.993
pH=7	0.034	0.996	7.400	0.005	0.996	0.037	0.969	0.996
pH=9	0.212	0.858	0.153	-0.305	0.986	0.051	2.508	0.946
The clay mineral separated from the non-calcareous soil								
pH=5	0.096	0.996	18.250	-0.004	0.996	0.047	1.174	0.998
pH=7	0.124	0.992	27.600	0.005	0.994	0.146	0.957	0.993
pH=9	0.145	0.935	32.600	0.025	0.964	0.497	0.689	0.964
The clay mineral separated from the calcareous soil								
pH=5	0.064	0.982	11.500	-0.004	0.997	0.026	1.224	0.991
pH=7	0.078	0.997	15.800	0.005	0.997	0.083	0.986	0.997
pH=9	0.145	0.935	20.500	0.010	0.988	0.260	0.873	0.982

a, b are the maximum monolayer adsorption capacity (mg kg⁻¹soil), affinity coefficient (L mg⁻¹), x and 1/n are intercept and slope, respectively

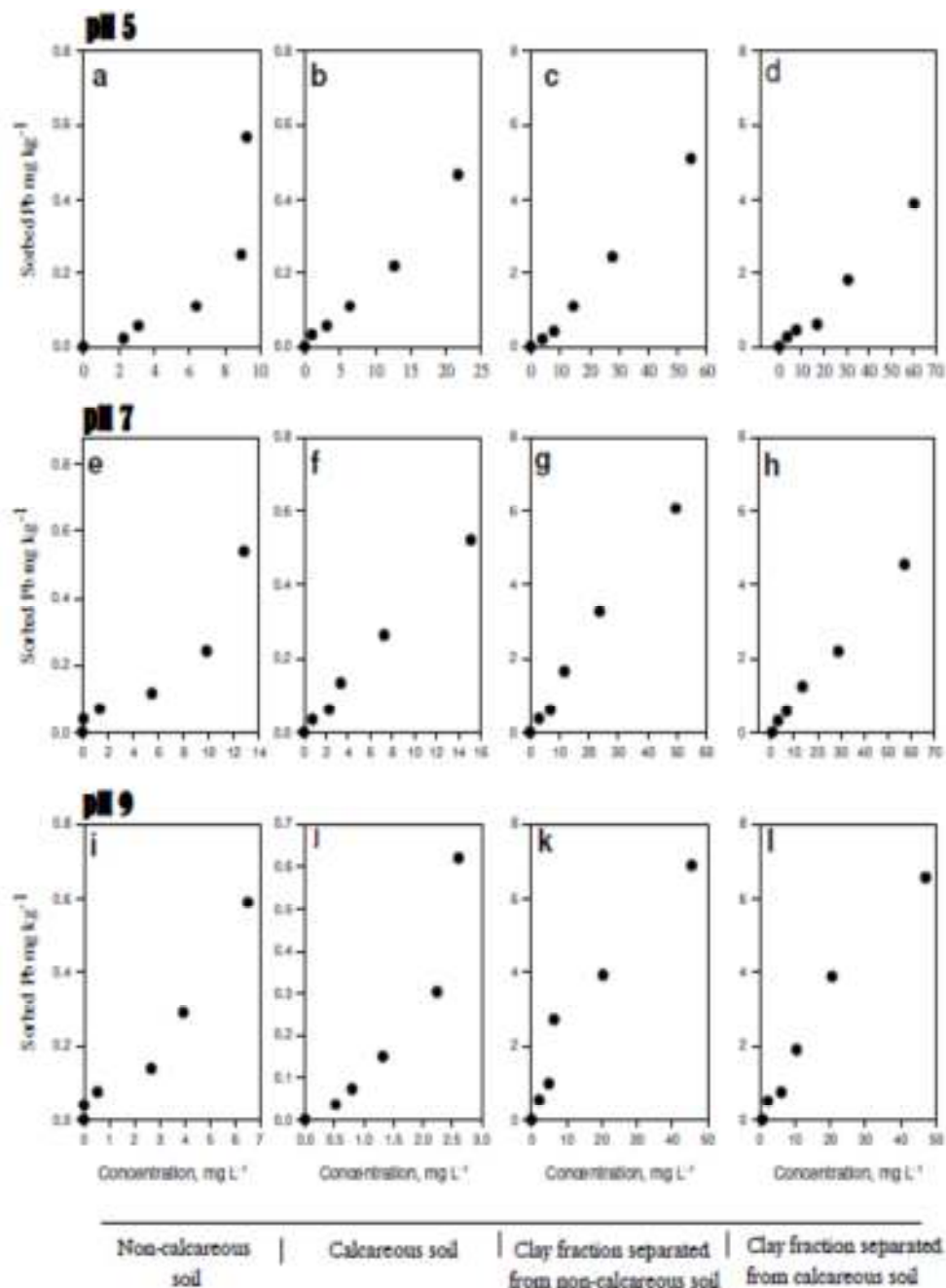


Fig. 4. Sorption of Pb on soils and their separated clay fractions as affected by its equilibrium concentrations.

Boron sorption on the investigated soils and their investigated clay fractions

Effect of the initial B concentrations and pH values on B sorption on soils and clay minerals

Sorption of the metalloid B on the investigated soils and their separated clay fractions increased noticeably with increasing the initial concentration of B in the metal-soil or clay fraction systems (Fig. 5). Such increases seemed observable with increasing the pH of the equilibrium systems from 5 to 9. Similar results were recorded by Communar and Keren (2006). This might take place because boric acid is the predominant species of B at pH below pKa (9.23 at 25°C) (Goldberg and Su, 2007). On the other hand,

increasing pH is associated with the buildup of $B(OH)_4^-$ (borate ion) (Chaudhary *et al.*, 2005); thus, sorption of borate ion probably takes place on the broken edges of clay minerals by replacing the hydroxyl groups (Singh and Mattigod, 1992). Generally, clay fractions separated from the investigated soils exhibited higher affinity to B from the equilibrium systems than the investigated soils themselves did. Sorption of B on the clay fractions was estimated to be 10 times higher than that occurred on the studied corresponding soils. On the other hand, B sorption was relatively higher on the clayey calcareous soils than that in the clayey non-calcareous one. This indicates that calcite particles probably increased the affinity of soils to retain B.

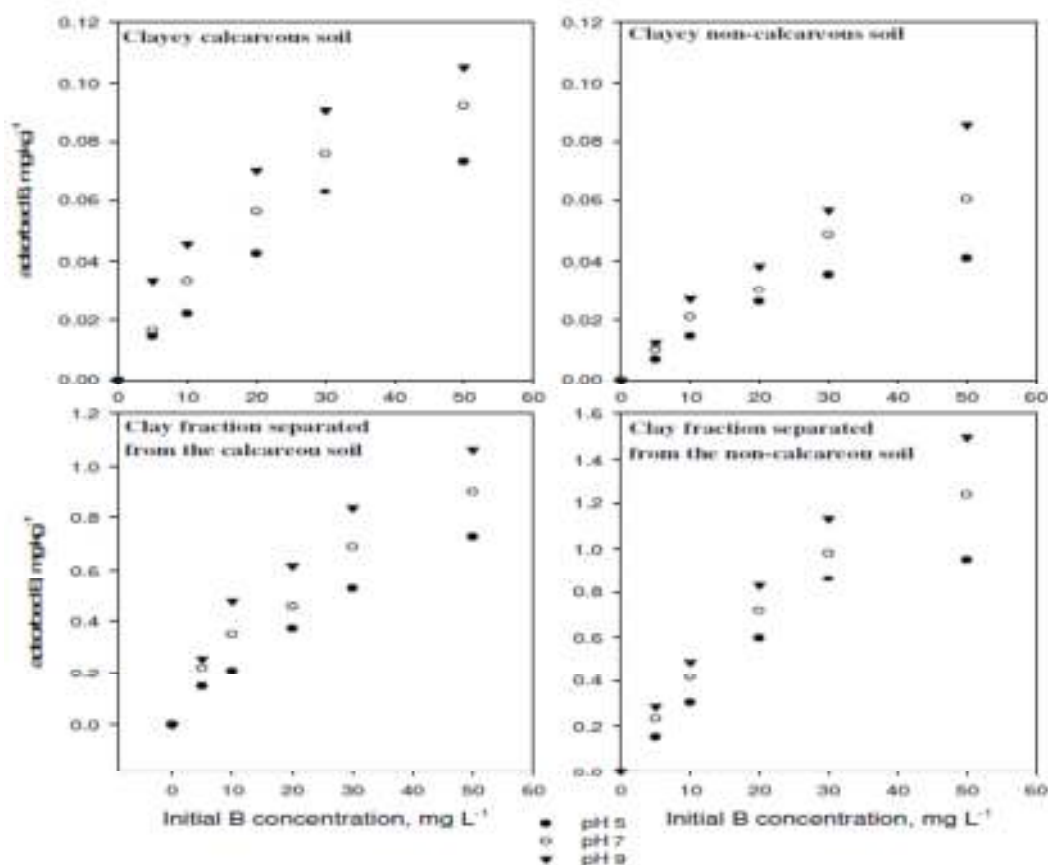


Fig. 5. Sorption of B on soils and the separated clay fractions as affected by the initial concentrations of the applied B under different pH values.

Sorption of B on soils and their separated clay fractions versus its equilibrium concentration

Sorption of B on the investigated soils and their separated clay fractions systems were represented graphically versus the concentration of B in the equilibrium systems (Fig. 6). These relations were fitted to the different adsorption isotherm models. The parameters calculated from these models are presented in Table 4.

According to the highest “r²” values, Langmuir isotherm model seemed to be the most efficient model fitting the sorption of B on soils and clay minerals. The values obtained herein were comparable to those recorded by Steiner and Lana (2013) who found that the “a” value ranged from 0.2 to 1.7 L mg g⁻¹, while the b value ranged from 0.004 to 0.049L g⁻¹ soil. This indicates that sorption of B took place in monolayers (Tan, 1998) probably as ligand exchange on the reactive surface hydroxyl groups (Goldberg and Su, 2007). According to Majidi et al. (2010), sorption of B on calcareous soil takes place as outer-sphere complex.

It is worthy to mention that the maximum monolayer adsorption capacity (“a” values) increased with increasing the pH of the metalloids soil or clay fraction suspension from 5 to 9 by 1.3, 2.3, 1.5 and 2.5 fold for the clayey soil, calcareous soil, clay fraction separated from the non-calcareous soil, clay fraction separated from the calcareous soil, respectively. In the calcareous soil, the affinity constant seemed to decrease with increasing the pH of the suspension and this result is confirmed by the findings of Steiner and Lana (2013) who recorded that the bonding energy of the B-sorption on soils decreased with

increasing the pH of the aqueous solution. On the other hand, this constant seemed to increase in both the soil and on the clay fraction separated from the calcareous soil with increasing the pH of the suspensions. In case of the clay fraction separated from the non-calcareous soil, this constant remained relatively unchangeable.

Table 4. Calculated parameters and “r²” values for the adsorption isotherm models of B on soils and clay minerals

	linear isotherm		Langmuir isotherm			Freudlich isotherm	
	Kp	r ²	a	b	r ²	x	1/n R ²
The non-calcareous soil							
pH=5	0.001	0.899	0.139	0.036	0.982	0.008	0.607 0.966
pH=7	0.003	0.878	0.145	0.055	0.997	0.013	0.553 0.975
pH=9	0.003	0.797	0.179	0.176	0.436	0.028	0.377 0.964
The calcareous soil							
pH=5	0.001	0.889	0.086	0.035	0.989	0.004	0.616 0.962
pH=7	0.001	0.932	0.111	0.027	0.984	0.005	0.666 0.976
pH=9	0.006	0.976	0.200	0.015	0.987	0.005	0.757 0.991
The clay mineral separated from the non-calcareous soil							
pH=5	0.022	0.883	1.742	0.031	0.976	0.091	0.637 0.948
pH=7	0.028	0.931	2.194	0.031	0.998	0.119	0.631 0.987
pH=9	0.034	0.948	2.667	0.030	0.999	0.643	0.632 0.996
The clay mineral separated from the calcareous soil							
pH=5	0.015	0.973	0.607	0.028	0.996	0.047	0.720 0.966
pH=7	0.102	0.936	1.500	0.032	0.977	0.092	0.599 0.986
pH=9	0.022	0.901	1.490	0.051	0.986	0.138	0.543 0.984

“a”, “b” are the maximum monolayer adsorption capacity (mg kg⁻¹ soil), affinity coefficient (L mg⁻¹), x and 1/n are intercept and slope, respectively

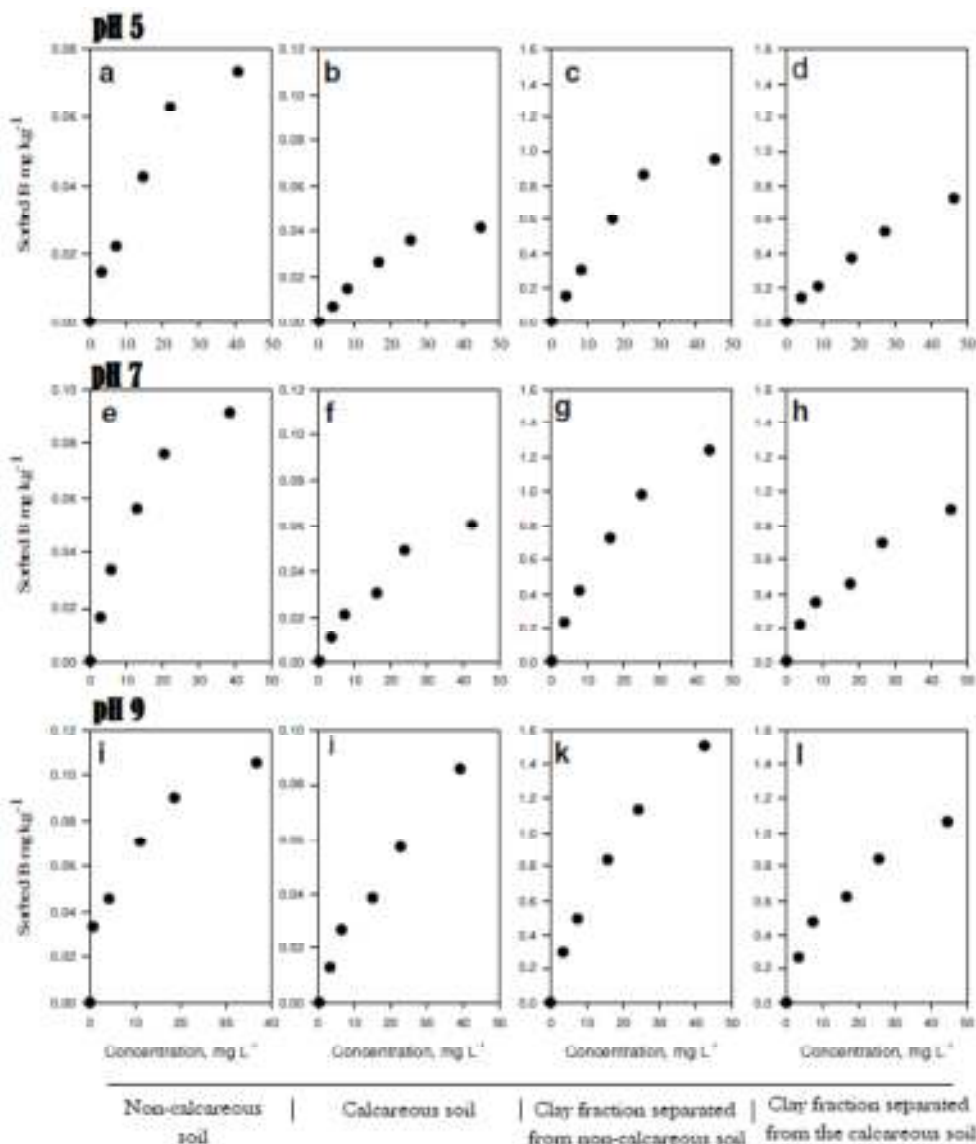


Fig. 6. Sorption of B on soils and clay minerals as affected by their equilibrium concentrations.

In conclusion, adsorption of Pb and B on the investigated soils seemed to be the dominant mechanism controlling their mobility in soils even at pH 9. The clay fractions separated from these soils were of higher affinity to immobilize Pb and B; however, the actual sorption capacities and affinities of soils remained much lower than those of the separated clay fractions.

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إدمصاص الرصاص واليورون على الأراضي ومفصولاتها الطينية

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يعتبر التلوث أحد التهديدات الرئيسية التي تمثل خطراً محتملاً للإنسان والحيوان، وخاصة العناصر السامة المحتملة (PTE) الموجودة بالتربة والتي تعتبر غير قابلة للتحلل البيولوجي ويمكن أن تستمر في التربة لسنوات. ويعتقد أن معادن الطين في التربة من بين العوامل الرئيسية التي تلعب دوراً في ذلك. ولذا يهدف هذا البحث إلى محاولة تحديد ميكانيكيات الإدمصاص لهذه العناصر السامة تحت الدراسة (الرصاص و اليورون) الموجودة في تربة طينية وأخرى جيرية تحت درجات حموضة pH مختلفة ٥ و ٧ و ٩. وتبلغ نسبة الطين في التربة الطينية ٥٨.٢٥% ونسبة كربونات الكالسيوم ٢٤.٨ جم/كجم، بينما تبلغ نسبة الطين في التربة الجيرية ٤٠.٧٥% ونسبة كربونات الكالسيوم ٢٨٩.٩ جم/كجم. تم فصل الجزء الطيني من الأراضي تحت الدراسة وتحديد أنواع المعادن الطينية السائدة في هذه الأراضي باستخدام تحليلات حيود الأشعة السينية. وكان معدن طين المونتوريللونيت Montmorillonite هو المعدن الطيني السائد في التربة الطينية، بينما كان معدن طين الكاولينيت Kaolinite و البالوريسكيت palyorskite هي المعادن السائدة في التربة الجيرية. ازداد إدمصاص الرصاص و اليورون على الأراضي والمعادن الطينية المفصولة منها تدريجياً مع زيادة التركيز الأولي لهذه الأيونات في أنظمة التوازن، خاصة مع زيادة الرقم الهيدروجيني من ٥ إلى ٩. أظهرت معادن الطين المفصولة إدمصاص الأيونات تحت الدراسة بقيم أعلى بكثير من تلك التي حدثت في الأراضي. وكانت معادلات إدمصاص فان فرويندلخ Freundlich النموذج الأكثر كفاءة في وصف نتائج تجارب الإدمصاص بالنسبة لعنصر الرصاص في كل من التربة الطينية والجيرية ومعادن الطين المفصولة منهما، بينما كانت معادلات إدمصاص لانجمير أكثر ملائمة لوصف نتائج تجارب الإدمصاص بالنسبة لعنصر اليورون في كل من التربة الطينية والجيرية ومعادن الطين المفصولة منهما. وقد بينت النتائج أن إدمصاص الرصاص و اليورون على معادن الطين هو الميكانيكية المسيطرة على حركتها في التربة حتى عند الرقم الهيدروجيني ٩، وكانت قدرات الإدمصاص الفعلية (أقصى إدمصاص) والارتباطات في التربة (معامل الأفضلية) أقل بكثير من تلك التي حدثت في معادن الطين المفصولة منها.