CHEMICAL BEHAVIOR OF LEAD IN A SANDY SOIL LONG-TERM IRRIGATED WITH SEWAGE EFFLUENT

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ABSTRACT

Three soil profiles were dug in Abuo-Rawash farm, Giza, Egypt; two of them were nearly highway and subjected to continuous irrigation with effluent up to 40 years, the other one was not contaminated. The collected soil samples under contamination condition were investigated for their total content Pb content, availability and distributions among the different chemical fractions,. The non contaminated one was subjected to adsorption- desorption reaction to asses the ability of soil for Pb retention.

The obtained results showed that the level of both total and DTPA-extractable Pb as well as those of some detected heavy metals, i.e, Fe, Mn , Zn, Cu, Ni and Cd were, to some extent higher, particularly in the surface layers of the contaminated soils. However, the soil samples (0-10cm) taken 5m from road side contained markedly higher total Pb amounts reaching 20 and 28 folds those of the non contaminated one and are considered phytotoxic. Likewise, the corresponding values of the chemically available Pb were 13.7 and 23 fold, respectively and exceeded the maximum background level. Sequential extraction procedure results showed that , although the exchangeable Pb fraction increased due to increasing soil contamination , most of the added Pb to the studied soils was associated with the residual and/or the organically bound fraction indicating the expected high efficiency of soil organic matter and clay in immobilizing Pb. Thus, the tested soil has relative ability to minimize the immediate risk of the added Pb.

Lead adsorption was confirmed to the Langmuir isotherm and the calculated adsorption maximum value (b) revealed that Pb saturated up to 54.5% of the cation exchange capacity of the non contaminated soil. Desorption of the adsorbed Pb represented about 57.1%. This means that more than 40% of the adsorbed Pb was considered not chemically available (retained).

Keywords: Lead, sewage effluent, chemical behavior, sorption-desorption, sequential extraction ,sandy soil.

INTRODUCTION

One of the important sources of pollution with heavy metals occurring in some cultivated soils of Egypt, is the continuous irrigation with sewage effluent. The prolonged period of irrigation with sewage effluent has markedly accumulated certain heavy metals in most plants. However, heavy metals are present in soil in different forms with varying degrees of mobility and availability to plants.

The environmental effect of heavy metals is related to the level of various forms and the rate with which the less mobile forms are transferred to the more mobile ones. So, the fractionation procedures of heavy metal are valuable in predicting bioavailability, metal leaching rates and transformations between chemical forms in both agricultural and polluted soils. Sequential extraction procedure for heavy metal fractionation was successfully used by

several authors, i.e, Voegelin *et al.,(*2008) ,Iwegbue (2007), Elsharawy and Elbordiny (2004) , Kabala and Singh (2001) and Aboulroos *et al.,* (1991).

The availability of heavy metal, such as lead is governed by sorption-desorption reactions at soil surfaces. The total lead concentration is not a reliable indicator of the bioavailability and mobile metal fraction in soils (Moreno, 2006). In fact, it is not always accurately reflects the actual metal concentrations in the soil solution. The availability of lead and other metals in soil depends on the way of the metal partitions between solid phases and the soil solution; it depends on various soil properties including pH, organic matter, clay content as well as Fe & Mn oxides (Wu *et al.,* 2003 ,Rieuwerts *et al.*, 1998 ,Elsharawy 1989 and Elsokkary 1979).

The most important chemical processes affecting heavy metal behavior and bioavailability in soils are those concerned with the adsorption of metals from the solution phase (Alloway ,1995).

The purposes of this investigation were (a) to determine the various chemical forms of Pb in the contaminated soil which governed the metal transformation and availability through sequential extraction procedure and (b) to determine the adsorbed as well as the desorbed amounts of Pb.

MATERIALS AND METHODS

Chemical forms of lead:
Soil sampling:
Three soil profiles were dug to the depth of 150cm in Abou- Rawash area ,Giza, *Typic torripsamments,*; two profiles represent the contaminated cultivated soils that had continuous addition of sewage effluent up to 40 years, at distance of 5 and 50 m far from the motorway, respectively, the third was unirrigated and uncultivated soil and assumed to be uncontaminated (control) . Each soil profile was sampled at depths of 0-10, 10-30, 30-60,60-90 and 90-150 cm. Three sub samples were taken from each layer to make a composite sample. The samples were air dried and prepared for the following analysis:

The routine analysis, i.e, mechanical analysis, organic matter content, soil pH, electrical conductivity and cation exchange capacity were performed according to the standard methods outlined by Klute (1986) , Page et al., (1982) and Jackson (1967) and are shown in table 1.The chemically available Pb was extracted from the studied soils using DTPA extractant , Lindsay and Norvell (1978),while total Pb was determined according to Jackson (1967) .

Table 1: Some physical and chemical characteristics of the studied soils (0-30 cm depth)

Soil	Particle size distribution, %				Texture class	pH (Paste)	ECe, dS/m	CaCO$_3$, %	CEC, meq/100 g
	C.sand	F.sand	Silt	Clay					
S1 #	56.1	28.2	9.9	5.8	L.S*	7.25	1.12	3.10	5.2
S2	48.4	26.2	15.3	10.1	S.L	7.12	0.84	2.43	11.9
S3	49.1	24.4	15.3	11.2	S.L	7.05	1.02	2.51	12.3

#S1: Unirrigated soil (control), S2: Irrigated with sewage effluent, taken 50 m from road side and S3: Irrigated with sewage effluent, taken 5 m from road side, respectively
* L.S and SL: loamy sand and sandy loam , respectively.

Sequential chemical extraction:

The sequential extraction procedure of Tessier *et al.,* (1979) was used to separate the different chemical forms of Pb in the layers of (0-10, 10-30 and 30-60cm) of the three studied soils to the following fractions: Exchangeable, carbonate bound, Fe and Mn oxides bound, organically bound and residual fractions. Lead in the various solutions was determined using atomic absorption spectrophotometer (AAS).

Adsorption and desorption of lead by soil:

The uncontaminated surface soil (0-10cm) was used for Pb adsorption and desorption studies. One g soil sample was put in 100 ml centrifuge tube, then receiving 50 ml of $Pb(NO_3)_2$ solution of various concentrations. The initial Pb concentrations varied from 0 too 140 mg/l and adjusted to pH 6,5. The samples were shaken for 24 hrs and then centrifuged at (4000xg for 30 min); Pb was determined in the supernatant using AAS. Each sample was replicated three times.The adsorbed Pb was calculated depending on the initial and final concentrations.

Pb adsorbed = Initial Pb conc., mg/l – Equilibrium Pb conc., mg/l

The data obtained were fitted to the Langmuir adsorption equation in the straight line form:

$$\frac{C}{x/m} = \frac{1}{kb} + \frac{C}{b}$$

Where ; Slope = 1/b and intercept = 1/kb

C: Equilibrium Pb concentration in solution, ug/ml,

x\m : The amount of Pb adsorbed , ug/g soil ,

b: The adsorption maximum or adsorptive capacity , ug/g,

k: Constant related to the bonding energy of Pb to the soil.

Langmuir coefficients were estimated using regression equation procedure.

Lead desorption :

The samples which were initially equilibrated with Pb solution of 140 mg/l were selected for Pb desorption . Five ml of 0.005 M DTPA (Lindsay and Norvell, 1978) were added to each sample in the centrifuge tube, shaken for two hrs. This was replicated three times , then centrifuged for 5 min. Lead was determined in the supernatant using AAS.

RESULTS AND DISCUSSION

Data listed in table 2 show total and DTPA-extractable amounts of Pb in the upper 30 cm layer of the investigated soil profiles. It is clear that the two soils irrigated with sewage effluent generally show drastic increase in amounts of total heavy metals compared to the non irrigated one. Such increases were several times higher and ranged between 1.8 and 16.6 folds that of control (S1), with the lowest increase for Fe and highest increase for Ni. This could be attributed to the continuous irrigation with sewage effluent up to 40 years which caused accumulation of such heavy metals, particularly in the surface layer. El-Gendi *et al.,* (1997) found that irrigation of sandy soil

of Abou-Rawash area with polluted waste water increased the total Cu, Zn and Fe to 125, 170 and 5 times that of the unirrigated one. Similar findings were previously found by Abdel-Aal *et al.*, (1991).

Table 2: Total and DTPA-extractable (Ext.) heavy metals , μg/g of the studied soils (0-30 cm depth).

Soil	Fe		Mn		Zn	
	Total	Ext.	Total	Ext.	Total	Ext.
S1**#**	9864	3.9	212	3.5	56.1	1.2
S2	17942	26.8	1197	26.9	234	11.2
S3	17596	24.4	1243	28.6	225	12.4

Table 2: Cont.

Soil	Cu		Ni		Cd	
	Total	Ext.	Total	Ext.	Total	Ext.
S1	31.7	0.8	2.96	0.28	0.42	0.05
S2	88.6	9.8	45.6	1.62	2.65	0.22
S3	79.5	10.2	49.2	1.41	2.50	0.20

#S1: Unirrigated soil (control), S2: Irrigated with sewage effluent, taken 50 m from road side and S3: Irrigated with sewage effluent, taken 5 m from road side, respectively

The DTPA-extractable heavy metals of the investigated soils (table 2) showed similar trend to that obtained for total metals content.

A marked increase in the chemically available heavy metals of the sewage effluent irrigated soils compared to the unirrigated one was noticed. The average increases of the two contaminated soils (S2 and S3) reached 6.5, 8.0 9.8, 12.4, 45.4 and 4 times those of the control (S1) for Fe, Mn, Zn, Cn, Ni and Cd, respectively.

Values of the total heavy metals detected in the investigated soils were compared with their levels considered by European Union, reported by Kabta-Pendias and Pendias (1992) and Alloway (1995) for maximum acceptable concentration in agricultural soils for plant growth, animal and human consumption. The present data show that among the detected metals, total Cu, Ni and Cd in the sewage effluent irrigated soils exceeded the permissible limits. However, the ranges of DTPA-extractable Zn and Cn exceeded the background levels given by Logan and Miller (1982).

Table 3 shows the detected values of both total and DTPA-extractable Pb as well as organic matter content in the different layers of the investigated soil profiles. As expected the data show that organic matter content in the different profiles layers of the soils irrigated up to 40 years with sewage effluent were obviously higher compared to the non irrigated soil (control). Thus, the repeated sewage effluent application to such soil increased their organic matter content, particularly in the upper layer of (0-10 cm) which reached about 6 fold that in the control (S1). The rate of this increase was reduced with increasing soil depth.

Table 3: Organic matter content, total and DTPA-extractable Pb, μg/g, of the studied soils in the different layers.

Depth, cm	O.M , %	Pb, mg/kg		A.I.##
		Total	Ext.	
Unirrigated soil (control)				
0-10	0.80	9.45	0.75	8.0
10-30	0.42	4.56	0.50	11.0
30-60	0.10	2.88	0.32	11.1
60-90	0.10	2.53	0.20	7.9
90-150	0.0	2.16	0.05	2.3
Soil irrigated with sewage effluent, taken 50 m from road side				
0-10	5.22	190	15.7	8.3
10-30	3.69	111	6.0	5.4
30-60	1.48	62.5	2.4	3.8
60-90	0.36	46.8	1.1	2.3
90-150	0.22	34.2	0.6	1.7
Soil irrigated with sewage effluent, taken 5 m from road side				
0-10	5.06	268	27.2	10.1
10-30	3.43	132	7.9	6.0
30-60	1.48	69.8	4.2	6.0
60-90	0.40	49.0	1.5	3.1
90-150	0.25	40.2	0.7	1.7
		50-300*	**7.9#**	
		100-400**		

* and** :Maximum total content (ug/g),Alloway (1995) and Kabata-Pendias and Pendias (1992) , respectively and # :Maximum background level extracted by DTPA(ug/g), Logan and Miller (1982).
A.I: availability index = (Ext) 100 /Total.

Total and DTPA-extractable Pb amounts were determined in the different layers of the contaminated soil samples that were taken at 50 and 5 m from the road side. The obtained data listed in table 3 and illustrated in fig. 1 show that the levels of either total or DTPA-extractable Pb in the tested soils increased with the application of sewage effluent and decreased with increasing distance from the road. The highest content was found in the upper layer (0-10 cm) of the soil profiles taken at 5 m from road side. This result could be attributed to the pollution by vehicle exhaust, the main source of Pb pollution in road side soils, since the studied contaminated soils (S2 and S3) are nearly high way as have been reported by Badawy and Helal (2002). The upper layer of (S2) and (S3) soil profiles contained total Pb reaching 20 and 28 folds those of the non contaminated soil (S1), respectively; similarly, the corresponding values of the DTPA-extractable Pb were 13.7 and 23 fold, respectively.

The total Pb content values of the upper layers (0-10 and 10-30 cm) of the two soil profiles irrigated with sewage effluent are considered phytotoxic according to Alloway (1995). Morever, the chemically available Pb detected in the surface layer (0-10 cm) of such soil profiles exceeded the maximum background reported by Logan and Miller (1982).

Fig. 1: Total and DTPA-extractable Pb of the upper layer (0-10cm) of the tested soil profiles.
S1: Non irrigated soil (control), and S2 and S3: Irrigated with sewage effluent, taken 50 m and 5 m from road side, respectively.

Sequential extraction procedure indirectly assesses the potential mobility and bioavailability of metals. The fractions studied are (i) exchangeable, (ii) bound to carbonate, (iii) bound to Fe & Mn oxides, (ic) bound to organic matter and (v) residual fractions. The levels of various Pb fractions in the investigated soils are shown in table 4. The obtained data show that the sum of the different fractions in the three studied soils was always less than the total Pb content. On an average, the sum of Pb fractions represented 66, 84.1 and 88.6% of the total Pb for (S1), (S2) and (S3), respectively. It seems that the suitability of the used method increased with increasing the total Pb content as have been reported by Tessier et al., (1979).

A highly significant correlation (r= 0.99) was obtained between total Pb and the sum of Pb fractions. Moreover, the extracted Pb fractions expressed as percentage of their sum in the three tested soils are shown in fig. 2.

The obtained data show that all Pb fractions increased with increasing total Pb content in the studied soils. The highest Pb amounts of different fractions were detected in he upper layer (0-10 cm), regardless of pollution intensity. Lead was markedly found to accumulate in the top soils because of their affinity with organic matter fraction. However, the two sewage effluent irrigated soils contained higher amounts of Pb fractions compared to the non irrigated soil (control).

Data also show that, in case of the uncontaminated soil, most of the total Pb content (40.2, 37.3 and 43%, S1 soil and 38.4 and 40.5%, S2 and S3 soils, respectively) was associated with the residual fraction, i.e. bound to primary minerals of the soil and/or precipitated as phosphate or silicates. The layer of (30-60 cm) of both contaminated soils (S2 and S3) showed similar trend (38.4 and 40.5%). However, the organically bound Pb fraction was

higher than the residual one in the surface layer of the contaminated soils, ranging from 36.1 to 40%. This result could be attributed to the high affinity of Pb to form complexes with organic substances as have been reported by McBride (1995) who added that lead has a high electro negativity and is considered to be a soft acid; it forms strong bonds with organic materials (high affinity for soil organic matter) .

Table 4: Different fractions of Pb sequentially extracted from the upper layers of the studied soils.

Depth cm	Pb fractions, $\mu g/g$					
	#Ex.	**Carb.**	**Ox.**	**Org.**	**Res.**	**Sum**
Unirrigated soil (control)						
0-10	0.30	0.65	1.31	1.41	2.46	6.14
10-30	0.06	0.43	0.75	0.69	1.15	3.10
30-60	0.04	0.25	0.43	0.38	0.84	1.95
Soil irrigated with sewage effluent, taken 50 m from road side						
0-10	9.23	17.6	21.1	58.5	55.5	162
10-30	4.80	7.11	13.2	34.00	33.3	92.4
30-60	2.35	4.10	9.37	15.7	19.7	51.2
Soil irrigated with sewage effluent, taken 5 m from road side						
0-10	14.9	15.9	23.6	99.5	87.0	241
10-30	8.24	7.42	11.7	48.7	39.9	116
30-60	2.62	4.28	6.54	21.9	24.1	59.5

#Ex., Carb., Ox., Org. and Res.: exchangeable, bound to carbonate, bound to Fe & Mn oxides, organically bound and residual fraction, respectively.

Heavy metals tend to form complexes with organic matter in the soil. This can be due to more phenolic and benzene-carboxilic groups present in humic and fulvic acids of the organic matter (Hung et al., 2005). In spite of that, Voeglin *et al.,* (2008) found that increasing sewage sludge application enhanced Zn mobility in soil possibly due to differences in chemical behavior of both elements of Zn and Pb.

The lowest Pb fraction was the exchangeable form, ranging from 2.1 to 4.9%, 4.6 to 5.7% and 4.4 to 7.1% from their sum in case of S1, S2 and S3 soils, respectively. As shown, it increased with increasing degree of contamination with Pb . Contribution of different metal pools in bioavailability portion could be attributed to the renewal additions of sewage effluent which partionate among different soil forms of the metal. Thus, Pb added to the contaminated soils either through sewage effluent or by vehicle exhaust, is distributed among different soil chemical pools with the greater amounts in the less mobile forms, i.e. residual, bound to organic and bound to oxides. Lena and Gade (1997) reported that the exchangeable forms and the carbonate bound heavy metal is the more mobile forms among the different fractions. This means that the soil has ability to minimize the immediate risk of the added heavy Pb through decreasing mobility, hence reducing its bioavailability. However, attention must be given for the continuous supply of Pb and other heavy metals to the agricultural soils.

Fig. 2: The Pb fractions of the upper layers of the studied soils expressed as   percentage of their sum.
Ex., Carb., Ox., Org. and Res.: exchangeable, bound to carbonate, bound to Fe & Mn oxides, organically bound and residual fraction, respectively.

Lead adsorption by soil:

The availability of heavy metal depends on the retention capacity of soil and on the particular solid phases to which the metal associate. Metal availability is governed by sorption- desorption reactions particularly with soil surface. The process of concentrating materials at the interface is called sorption. Data of Pb adsorption isotherm of the uncontaminated soil are shown in table 5a and graphically illustrated in fig.3. The constant-temperature equilibrium relationship between the mass of the adsorbate (metal) per unit mass of adsorbent (soil) (x), and the equilibrium concentration of the adsorbate in solution (C) , is called the adsorption isotherm.

Table 5a: Lead adsorption isotherm of the uncontaminated soil.

Initial Pb conc., μg/ml	Equi. Pb conc. (C), μg/ml	χ/m, μg/g	C/χ/m, μg/ml/ μg/g
20	0.8	960	$8.3*10^{-4}$
40	1.4	1930	$7.2*10^{-4}$
60	2.2	2890	$7.6*10^{-4}$
80	4.6	3770	$1.2*10^{-3}$
100	12.1	4395	$2.75*10^{-3}$
120	20.2	4990	$4.01*10^{-3}$
140	32.5	5375	$6.01*10^{-3}$

Fig.3: Langmuir isotherm for Pb adsorption onto soil.

As shown, values of the adsorbed Pb markedly increased with increasing the initial Pb concentrations equilibrated with the tested soil .This positive relationship is ensured by the linear isotherm obtained ,which indicates high affinity of the soil sorbent complex for Pb at the employed concentrations. Applying the Langmuir equation to the experimental data was evaluated by estimating simple correlation coefficient for C versus c/x/m ones; this resulted in a high significant correlation (0.99). which indicates that the data fit the Langmuir isotherm.

The calculated adsorption maximum (b) and the constant of bonding energy (k) derived form both slope and intercept of the Langmuir straight line equation, are given respectively in table 5b. The obtained results of Langmuir coefficients, (b) and (k), were 5.88 mg/g soil and 0.32 ml/ug ,respectively. In fact, it is useful to evaluate the sorptive capacity of soil for specific ion; in the present investigation, the adsorbed Pb saturated 54.5% of soil CEC.

However, heavy metal that is specifically adsorbed onto clay minerals and metal oxides may diffuse into the lattice structure of the minerals, then bind to pore spaces (Bradl ,2004). In fact heavy metal adsorption is basically adsorbed via two different mechanisms, namely specific adsorption, chemisorptions of inner-sphere complexes, and non-specific adsorption, outer-sphere complexes (Sposito ,1984).

Table 5b: Langmuir coefficients for Pb adsorption by the uncontam- inated soil.

Slope	Intercept	Pb adsorption maximum, b (mg/g)	Bonding energy, k (ml/µg)	r
$1.7*10^{-4}$	$5.23*10^{-4}$	5.88	0.32	0.998[**]

The affinity for metal binding varies with metal concentration .Comparing the adsorbed Pb amounts relative to the concentrations added initially revealed that Pb adsorption was found to be high at low initials concentrations and to decrease at incersed Pb levels .This means that the low Pb contaminated soil can adsorb the metal more efficiently compared to the high contaminated similar one. Similar finding was also obtained by Adhikari and Singh (2003) who found that at low concentration, Pb is preferentially sorbed at high-energy surfaces; at high concentration, however, it binds loosely to low – energy surfaces or precipitates. On the other hand ,although the present tested soil has loamy sand texture, it adsorbed considerable amounts of Pb and this could he explained that some of the added Pb to such soil are bound weakly to fine sand and ,especially silt, as have been also reported by Moreno *et al.*,(2006).

Desorption of Pb from soil:

Lead desorption was carried out by shaking the pre-Pb sorbed soil with 0.005 MDTPA solution for 2 hrs; however, some authors such as Moreno et al., (2006) used mineral salts solution of 1M NH**4**o Ac for Pb desorption from soil. The obtained data revealed that the desorbed Pb amount was 3.36 mg/g and this value represents 57.1% of the adsorbed Pb by such soil. The

non extractable Pb was considered retained and represents 42.9% from the adsorbed Pb.The retention of Pb is governed by some soil components such as, organic matter content, and primary minerals precipitates. The influence of the various soil characteristics on Pb adsorption was also reported by Trancoso et al., (2007) and Naidu et al., (1997). Howeve, Sipos et al., (2005) found that the organic matter adsorbs more Pb than clay minerals.

From the above mentioned discussion, it could be concluded that the continuous use of sewage effluent for irrigation led to accumulate organic matter as well as heavy metals, particularly soils in the upper layers of the studied soils indicating that Pb was mainly complexed with organic matter. Both total and chemically available Pb in the surface layers of the contaminated soils exceeded the maximum background levels. Moreover, auto exhausts is fairly effective in increasing total and DTPA extractable Pb, particularly at the short distance from road side. However, increasing levels of Pb added to the contaminated soils markedly increased the organically bound Pb as well as Fe-Mn oxides bound Pb fractions. This indicates, again, the high affinity of Pb to form complexes with organic matter.

The Pb adsorption fit the Langmuir isotherm; the non contaminated soil adsorbed Pb in considerable amounts (up to 54.5% of soil CEC). On the other hand, more than 40% of the adsorbed Pb did not desorb; this shows that the sites for the disposal of wastes enriched by Pb should have high CEC.

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السلوك الكيميائى للرصاص فى أرض رملية مروية لفترة طويلة بمياه الصرف الصحى

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أجريت هذه الدراسة على أراضى منطقة أبو رواش بالجيزة، حيث تم عمل 3 قطاعات أرضية تصل إلى عمق 150 سم، اثنين من هذه القطاعات لأرض تروى بمياه الصرف الصحى لفترة تصل 40 سنة احداها تبعد 5 متر والأخرى تبعد 50 م عن حد طريق السيارات، بينما القطاع الثالث لأرض لا تروى بمياه الصرف الصحى (أخذت للمقارنة). أخذت عينات من طبقات التربة المختلفة لدراسة كمية وصور وتيسر الرصاص كما تم دراسة ادمصاص- انطلاق الرصاص باستخدام الأرض غير الملوثة.

أوضحت النتائج:

أن محتوى الأراضى المروية بمياه المجارى من الرصاص قد ازداد عدة أضعاف ــ خاصة فى الطبقات السطحية وذلك بالنسبة للكمية الكلية (20-28 ضعف)، والميسرة كيميائياً (13.7-23 ضعف) مقارنة بمثيلاتها بالأرض غير المروية، وبذلك اجتازت الحدود المسموح بها, كانت الصورة الكيميائية السائدة للرصاص فى الأرض غير المروية بمياه المجارى هى الصورة المتبقية يليها الصورة المرتبطة بالمادة العضوية، بينما فى حالة الأراضى الملوثة بالرصاص كانت الصورة المرتبطة بالمادة العضوية هى الأعلى يليها الصورة المتبقية، كما ازدادت نسبياً الصورة المتبادلة نتيجة زيادة مستوى الرصاص فى الأرض ولو أن كميته كانت الأقل بين جميع الصور.

كان ادمصاص الرصاص على التربة غير الملوثة بهذا العنصر متمشياً مع معادلة Langmuir وكانت كمية الرصاص تمثل 54.5% من السعة التبادلية الكاتيونية، هذا وقد أمكن استخلاص حوالى 57% من الرصاص المدمص وبذلك اعتبرت الكمية المتبقية غير ميسرة كيميائياً أو مثبتة بواسطة مكونات التربة.

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