

RETENTION AND RELEASE OF CHROMIUM AND ZINC IN SLUDGE-AMENDED SANDY SOIL USING TRACER TECHNIQUE

Abdel-Bary, E.A*, E. A. EL-Naka*, M.F. Abdel-Sabour**
and S.M. Lotfy**

*Soil Sci. Dept., Fac. of Agric., Zagazig University

**Soil and Water Dept., Nuclear Res. Center, Atomic Energy Authority

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ABSTRACT: Sludge-amended soil could act as a sink for heavy metals by influencing the chemical and physical properties of soil. Sandy soil sample was amended with sludge materials at different levels (0%, 4%, 8%, 16%, and 32% w/w sludge). The retention and release of Cr and Zn from sandy soil amended with sludge were investigated. Results showed that increasing the contact time up to 336 hours did not significantly increase the metal retention reactions. Adsorption isotherms obtained for the studied soils were curvilinear. The curvature degree was higher for high rate application of sludge-soil mixtures (organic enriched soils) which indicates high affinity of the adsorbed metals. Calculation of metal adsorption maxima varied widely according to the tested metal and soil organic matter content. Adsorption maximum for Zn⁶⁵ ranged between 161 and 909 mg kg⁻¹ and from 303 mg kg⁻¹ to 1111 mg kg⁻¹ for Cr⁵¹. The highest values were reported for the organic enriched soils (high rate of sludge addition). The statistical correlation coefficients (R) between C/x/m and C for any adsorption curve of the investigated soils were highly significant and ranged from 0.848 to 0.940 for Cr and from 0.660 to 0.935 for Zn. The adsorption of Cr required 24 hours to reach equilibrium conformed to Langmuir adsorption isotherms. The bonding energy coefficients of adsorbed Cr⁵¹ and Zn⁶⁵ showed lowest values for the control sandy soil (no sludge addition) where the coefficient values ranged from 0.015 to 0.021 whereas, the organic enriched soils (high rate of sludge addition) had the highest bonding energy coefficients where values were around 0.03. Positive relationships were observed between Langmuir parameters and the content of soil organic matter and CEC. The release of Cr⁵¹ and Zn⁶⁵ from the investigated sludge-soil mixtures at 24, 96, 192 and 288 hours

decreased with time. The highest values of metal released were obtained in the control soils (no sludge addition) whereas, the organic enriched soil with high rate of sludge addition showed less capability to release metals. Results of Zn⁶⁵ and Cr⁵¹ release indicate that much of the retained metal had not been released from the soil with high levels of sludge addition. The magnitude of Cr released from the investigated sludge-amended soil mixtures was greater than Zn. The data were found to fit Langmuir isotherm. Addition of sludge to sandy soil as an amendment could constrain the solubility and mobility of heavy metals contaminants and therefore the pollution of surface and ground water systems. However, The immobilized metal may become bioavailable with time through natural weathering processes or through advanced decomposition of soil organic matter

INTRODUCTION

Land application of sludge has been a viable option for sludge management regardless the long-term environmental consequences. Sludge has a high adsorptive capacity at the time it reaches the soil. Sludges, soils, and solid wastes are multiphase materials which may contain metals in the solid, gaseous, and liquid phases. The composition of sludges depends on the original waste from which it was derived. The chemical form of the metal contaminant influences its solubility, mobility, and toxicity which depends on the source of the metal waste and the soil at the site. The most common metals found at contaminated sites are, in order: lead (Pb), Chromium (Cr), Arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), and mercury (Hg) (U.S. EPA, 1996). Chromium (Cr) is one of the less common elements and does not occur naturally in elemental form, but only in compounds. The major sources of Cr contamination include

releases from electroplating processes and the disposal of chromium containing waste (Smith et al., 1995). Cr (VI) is the form of chromium commonly found at contaminated sites and can also occur in +III oxidation state, depending on pH and redox conditions. Cr (VI) is the more toxic form and more mobile. It can be reduced to Cr (III) by soil organic matter, S²⁻, and Fe²⁺ (Chrotowski et al., 1991). Chromium mobility depends on sorption characteristics of the soil, including clay content, iron oxide content, and the amount of organic matter present (Smith et al., 1995).

Zinc (Zn) does not occur naturally in elemental form. It usually occurs in the +II oxidation state and forms complexes with a number of anions, amino acids and organic acids. At higher pH values, zinc can form carbonate and hydroxide complexes which control zinc solubility. Zinc readily precipitates under reducing conditions and when it is present at

very high concentrations, and may coprecipitate with hydrous oxides of iron or manganese. Sorption of zinc increases a pH increases and salinity decreases (Smith et al., 1995).

Adsorption of metals from the aqueous phase to the solid phase and their subsequent desorption are the most important chemical processes affecting the mobility and bio-availability of metals in soils. Adsorption is the kinetic reaction based on thermodynamic equilibrium rules. The forces involved in the adsorption of ionic species at charged surfaces are electrostatic and can be explained by Coulomb's law of attraction between unlike charges and repulsion between like charges. At metal equilibrium either the Langmuir or the Freundlich equations for adsorption isotherms can describe concentrations adsorption by soil particles. Ion exchange, precipitation or co-precipitation and chelation can adsorb metals in soils but often it is difficult to identify one precise mechanism responsible for the adsorption of metals in any particular soil (Lai and Stewart, 1994).

Soil components, clay minerals, hydrated metal oxides, and organic matter are considered to be the most important group in contributing to and competing for the sorption of trace elements. Blume and Brummer (1987) described bonding capacity of the main soil components and indicated that organic matter fix very strongly Cr^{3+} , Fe^{3+} , Pb, and Hg, while fix fairly Cd, Ni, and Co, and

fix slightly Mn and Zn. Clay minerals fix very strongly only Fe^{3+} , fix relatively slightly Cd, Co, and Ni While the other trace metals are bound rather fairly. Sesquioxides fix very strongly Cr^{3+} , Hg, and Pb, and fix relatively strongly all other metals. Also, Anderson and Christensen (1988) indicated that Zn and Co sorption into soils were influenced by the presence of clay and hydrous oxides of Fe and Mn.

The addition of organic amendments to Cr(VI)-contaminated mineral soil enhanced the reduction of Cr(VI) to Cr(III), thereby reducing the bioavailability of Cr and these organic amendments provided a source of electron donor (Bolan et al., 2003). King (1988) reported that the retention of metals by soils was independent of CEC, whereas the presence of Fe oxides and clay content in soil were more important. Alloway et al. (1990) showed that CEC was only important for soils treated with sewage sludge probably because of their higher organic matter content. Abdel-Sabour and Soliman (1990) found that the retention capacity of Zn^{65} tends to be higher with increasing soil organic matter and clay content. The relative exchangeable and organically bound Zn fraction increased with increasing Zn^{65} applied, and the percentage of Zn^{65} retention was 61.1 and 95 % of applied Zn^{65} for sandy and alluvial soils, respectively. Reddy and Dunn (1986) showed that clay soils with high CEC had a higher capacity to

adsorb Ni and Zn from equilibrium solutions of metal salts compared with a low CEC sandy soil. Naidu et al. (1997) studied the sorption of heavy metals in different types of soils and they found that adsorption of metal ions by variable charge soil and minerals increases as their pH, clay and organic matter contents increase. Stewart et al. (2003) stated that soils with higher quantities of clay, inorganic C (i.e., carbonates), higher pH, and higher cation exchange capacity generally sequestered more Cr(III).

Korboulewsky et al. (2002) stated that in the long run, application of sewage sludge compost (10 Mg ha⁻¹) increased soil organic matter and the accumulation of P in the soil may reach concentrations that will pose a risk to surface waters and ground water. Bjerre and Schierup (1985) found that organic matter and oxides preferentially bound lead, copper and zinc by oxides and inorganic matter but Cd was bounded by inorganic and organic soil components. Increasing concentration of SO²⁻ or PO³⁻ and organic ligand such as EDTA was effective in de-sorbing Cd from adsorbed surfaces. The metals are immobilized by soil organic matter in the order Cu > Cd > Zn > Pb and the immobilization effect depends on soil reaction and the kind of mineral components present in soil Christensen (1984). The objectives of this work were two-fold. First, to characterize the behavior of some heavy metals (Zinc⁶⁵ and Cr⁵¹) in

sludge-amended soils as affected by its physical and chemical properties. Second, to describe the sorption and desorption of these metals (Zinc⁶⁵ and Cr⁵¹) using the batch reaction method and Langmuir isotherms.

MATERIALS AND METHODS

Preparation of soil and sludge mixtures

A surface sandy soil sample (0-30 cm) was collected from the Experimental Farm of Nuclear Research Center, Enshas, EL-Sharkyia governorate. The conventional analyses of soil samples were as follows: soil separates: 90.5% sand, 6.3% silt, 3.2% clay, and 0.1% CaCO₃. Some chemical properties are: EC (1:1) 0.5 dSm⁻¹, pH (1:2.5) 8.2, and organic matter 1.7%.

Dredged sludge sample was collected from Mostorod industrial wastewater collector drain, north of Cairo. Both soil and sludge samples were air-dried, ground, and passed through 2mm sieve to insure the homogeneity of the bulk. Soil was amended with sludge material at five rates (0%, 4%, 8%, 16%, and 32% w/w sludge) to establish a soil-sludge mixtures in order to simulate five different levels of sludge-amended soil. Soil-sludge mixtures were subjected to the following analysis: Particle size distribution according to Piper (1950). Organic matter, CEC, EC, as well as initial content of Cr and Zn according to standard method of Jackson (1973). The physical and chemical characteristics of the different sludge-soil mixtures are shown in Table (1).

Table 1. Some chemical properties of the soil-sludge mixtures used in the experiment.

Rate of sludges applied to soil, %	pH	EC, dS m ⁻¹	CEC, cmole L ⁻¹	O.M, %	Initial conc., mg kg ⁻¹	
					Cr	Zn
0	8.21	0.51	9.30	1.70	12.2	205
4	7.82	1.10	12.6	2.70	24.0	288
8	7.71	1.30	14.8	3.15	37.4	371
16	7.52	1.51	18.3	3.70	46.6	526
32	7.31	2.13	25.7	5.37	60.9	689

Retention and release experiments

Soil-sludge mixtures samples were exposed to a laboratory experiments to determine the capacity of these mixtures to retain and release chromium and zinc as a heavy pollutant metals incorporated into the mixtures. The following procedures were used:

A) Retention experiment

This experiment was performed at ambient temperature for each tested metal (Zn and Cr) at different metal concentrations namely, 0.01, 0.1, 1.0, 10 and 100 mg/l. Four grams of each dried soil-sludge samples were weighed in 50 ml centrifuge tube, then 40 ml of 0.005 M Ca(NO₃)₂ as a background solution was added containing different metal levels as mentioned above. Carrier-free Zn⁶⁵ and Cr⁵¹ were added to each solution to facilitate metal analysis. Suspension were equilibrated on Wrist-action shaker overnight for different time intervals namely, 0, 2, 24, 48, 72, 144 and 336 hours. After

each equilibrium time the soil suspension was centrifuged at 5000 rpm and the activity of the metal in question in 1 ml of the clear supernatant was counted using HPGe-detector connected to multi channel analyzer. The concentration of Zn and Cr in the sample solutions was calculated at each sampling time using the following equation (Amacher et al. 1986).

$$C = C_0 [(A-B \text{ kg}) / (A_0 - B \text{ kg})]$$

Where: C is the concentration of metal in soil solution at time of sampling (mg l⁻¹), C₀ is the concentration of metal in solution before reaction with soil (mg l⁻¹), A is the activity of radionuclide in solution at time of sampling (cpm), A₀ is the activity of radionuclide in solution before reaction with soil (cpm), and Bkg is the background activity (cpm). Then, the adsorbed metal was calculated as the difference between initial and final metal concentration. The data were statistically best-fitted to the linearized Langmuir equation.

B) Release experiment

The release experiment was conducted according to Amacher et al., (1986). Metal adsorbed on soil sample after 336 hours at retention (in the retention experiment) was centrifuged for 5 minutes at 2000 rpm, then 20 ml of each supernatant was withdrawn. Aliquot of supernatant was assayed for each radionuclide. Another 20 ml of 0.005 M $\text{Ca}(\text{NO}_3)_2$ was added to each soil sample and was shaken for 24 hours then centrifuged and another 20 ml of the supernatant was withdrawn for counting. These steps were repeated four times to ensure complete replacement for the soil solution. Then the final suspensions were left for 48 hours on shaker, and 1 ml of each supernatant was withdrawn for counting. This step was repeated four times at 48 hours intervals. After centrifugation, metal concentration was determined in the supernatant to calculate the amount of metal desorbed.

RESULTS AND DISCUSSION

Characteristics of soil-sludge mixtures

Mixing sandy soil with sludge materials altered the chemical properties of mixtures. Data in table (1) show that soil organic matter content increased from a value of 1.7% in the control sandy soil (no sludge addition) to a value ranged from 2.7% for the low rate sludge addition (4%) to 5.37% for the high rate sludge addition (32%). Cation

exchange capacity (CEC) also increased from a 9.3 cmol kg^{-1} to a maximum value of $25.7 \text{ cmol kg}^{-1}$. EC values were increased from 0.51 dS m^{-1} to 2.13 dS m^{-1} . pH values were also decreased as increasing the rate of sludge addition where its values declined from 8.21 in the no-sludge addition mixtures to 7.31 in the high rate sludge addition mixtures.

Metals Retention

The effect of contact time on Zn and Cr retention in different soil-sludge mixtures suspensions is shown in Fig (1). It is clear that the retention of all tested metals has reached equilibrium after two hours, simultaneously. Increasing contact time up to 336 hours did not significantly increase the metal retention reactions. This result may suggest that the adsorption reactions of tested metals occurred simultaneously in any tested soil.

The amounts of Zn or Cr adsorbed on the investigated soils were plotted as a function of equilibrium concentration. Adsorption isotherms obtained for the studied soils were curvilinear. The curvature degree was higher for high rate application of sludge-soil mixtures (organic enriched soils) as it is shown in Fig (2), which indicates high affinity of the adsorbed metals. Langmuir adsorption isotherms for the tested metals in the selected soils are shown in Fig (3). The statistical correlation coefficients (R) between $C/x/m$ and C for any adsorption curve

of the tested soils were highly significant and ranged from 0.848 to 0.940 for Cr and from 0.660 to 0.935 for Zn (Table 2). The adsorption parameters suggested high affinity for tested metals in receiving either sewage effluent or industrial wastewater, similar results were found by Singh et al.,(1998). Calculated metal adsorption maxima varied widely, ranging from 161 up to 909 mg kg⁻¹ for Zn⁶⁵, and from 303 to 1111 mg kg⁻¹ for Cr⁵¹. The highest values were reported for the organic enriched soils (high rate of sludge addition), while the lowest ones were reported for control sandy soil (no sludge addition). Krishnasamy et al., (1998) indicated that the adsorption of Cr required 24 hrs to reach equilibrium and Cr adsorption on soils conformed to Langmuir adsorption isotherms. They reported that the sorption maxima ranged from 6.3 to 11.3 mg/g in original soils and 1.2 to 3.11 mg/g in organic-matter-oxidized soils.

The bonding energy coefficients of adsorbed Cr⁵¹ and Zn⁶⁵ are shown in Table (3). In general, the lowest values were reported for the control sandy soil (no sludge addition) where the coefficient values ranged from 0.015 to 0.021, whereas the organic enriched soils (high rate of sludge addition) had the highest bonding energy coefficients where values were around 0.03. Positive relationships were observed between Langmuir parameters and the content of soil organic matter and clay as well as soil CEC (Fig. 3). There are no constant relationships between Langmuir parameters and both soil pH and CaCO₃ content. Similar results were reported by Aide (1992). The retention capacity of Zn⁶⁵ tends to be higher with increasing soil organic matter and clay content and therefore the soil CEC (Abdel-Sabour and Soliman, 1990). They added that both relative exchangeable and organically bound Zn fraction increased with

Table 2. Langmuir constant and linear equations for metals adsorption by the investigated soil-sludge mixtures.

Metal	Sludge rate, %	Adsorption maxima (mg kg ⁻¹)	Bonding energy (k)	Equation	R
Cr	0	303	0.021	C/x/m=0.0033 C+0.1095	0.939
	4	588	0.024	C /x/m=0.0017 C+0.0691	0.848
	8	714	0.025	C /x/m=0.0014 C+0.0542	0.892
	16	1000	0.026	C /x/m=0.001 C+ 0.0477	0.910
	32	1111	0.030	C /x/m=0.0009 C+ 0.038	0.940
Zn	0	161	0.015	C /x/m=0.0062 C+0.2075	0.935
	4	333	0.015	C /x/m=0.003 C+0.141	0.816
	8	625	0.016	C /x/m=0.0016 C+0.1038	0.783
	16	769	0.021	C /x/m=0.0858 C+0.0858	0.696
	32	909	0.030	C /x/m=0.0011 C+0.0692	0.661

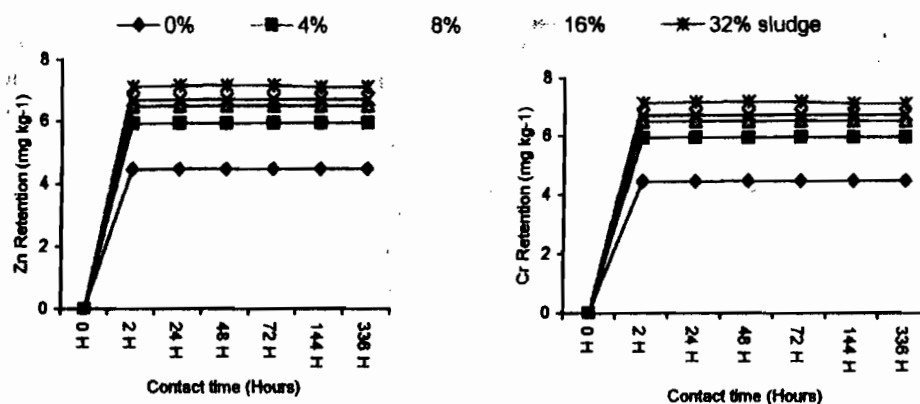


Fig.1. Effect of contact time on Zinc and Cr retention in the different soil-sludge mixtures.

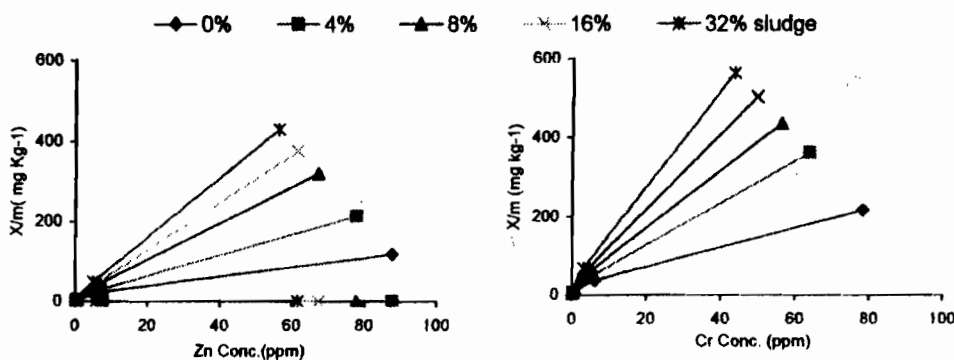


Fig. 2. Relation between adsorbed metals and different applied metal concentrations in the tested soil-sludge mixtures after equilibrium.

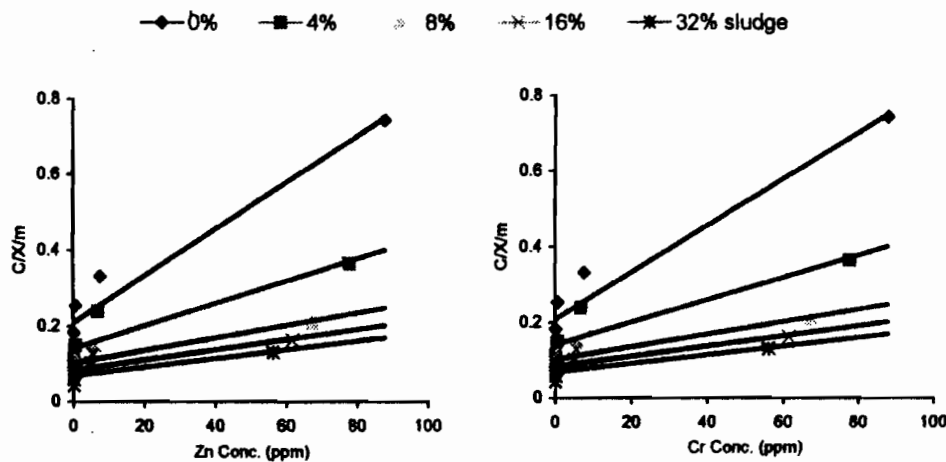


Fig.3. Langmuir isotherm curves of Zn and Cr for the different soil-sludge mixtures soils

increasing applied Zn^{65} . The percentage of Zn^{65} retention was 61.1 and 95 % of applied Zn^{65} for sandy and alluvial soils, respectively. Naidu *et al.*, (1997) studied the sorption of heavy metals and found that adsorption of metal ions by variable charge soil and minerals also increases as their pH, clay and organic matter contents increase.

The pH dependency of Cd, Cr(III), Cr(VI), Hg and Pb uptake by 14 different types of minerals and soil materials was investigated (Arnfolk *et al.*, 1996). Physical and chemical characteristics of the solids were correlated with metal uptake. Their results verified the importance of geochemical parameters of soils such as organic content, type of clay mineral, presence of complexing ions, and redox-potential for controlling metal uptake. They concluded that the retention of those metals was strongly dependent on organic content of the materials studied. Montmorillonite (in

bentonite and smectite) showed the highest uptake of Cd, Cr(III) and Pb among all minerals and soil materials, while illite and kaolinite showed lower uptake values. They observed that at low pH, the uptake percentage of Cr(VI) by organic soils was higher than of any other metal ions. The uptake of Hg was low in comparison to other cations, which was explained by formation of soluble Hg (Cl)₂ or Hg(Cl)₄²⁻ complexes.

Metals Release

The adsorption and desorption processes were described by the Langmuir or Freundlich isotherm (Sposito, 1979). Although the most important factors which govern these processes are carbonate content (HCO₃), CEC, and Eh-pH of the system, the adsorption capacity of organic matter can be of great importance. The release of Cr⁵¹ and Zn⁶⁵ from the investigated soil-sludge

Table 3. Correlation between some soil properties and Langmuir parameters for Cr⁵¹ and Zn⁶⁵ retention after 336 hours of reaction.

Metals	Langmuir parameters	Soil properties				
		Clay	pH	CEC	O.M	CaCO ₃
Cr ⁵¹	b	0.922	-0.986	0.944	0.946	0.964
	k	0.855	0.828	-0.655	-0.666	-0.859
Zn ⁶⁵	b	0.901	-0.964	0.935	0.937	0.948
	k	-	0.822	-0.709	-0.746	-0.945
		0.956				

b: Adsorption maxima.

K: Bonding energy.

mixtures is shown in Fig. (4) and Fig. (5), respectively. To simplify the discussion, only data points of metals released at 24, 96, 192 and 288 hours are shown in the plots. It is obvious that the retention reactions of the tested metals were not reversible. The decreased rate of metals released with time suggested that the retention reactions were approaching equilibrium state. However, after 288 hours of reaction much of the retained metal had not been released from the organic enriched soil with high rate of sludge addition (Fig.4). The magnitude of Cr released was greater than Zn at any of the investigated soil-sludge mixtures. It is clear that the amount of released metal depends on the initial metal concentration in soil (the amount of retained metal).

Although Cr may be present in soil as an anion under oxidizing conditions (Bartlett and James, 1979), it is generally expected to behave as a cation. The retention of organic enriched sludge-soil mixtures indicated that Cr had a strong affinity for organic matter and the extracted potential for Fe-Mn oxides. Amacher et al., (1986) illustrate the relationship between the amount of Cr⁵¹ retained by soil and Cr concentration in solution using either the two-surface Langmuir or Freundlich models. They added that the significant fraction of Cr⁵¹ retained by the soil was not released to solution and was not exchangeable, indicating that some irreversible retention of Cr⁵¹ occurred.

This is in agreement with the work of Sheppard and Thibault (1991). The role of organic ligand on metal adsorption was investigated by Abd-Elfattah and Wada (1981). They stated that the selectivity of adsorption reveals a possible formation of the coordination complexes of heavy metals with deprotonated OH and COOH groups as ligands. This specific sorption is well illustrated by heavy metals having high affinities for organic matter and the surface of oxides. This phenomenon has great importance in the nutrient supply to plants and in soil contamination. As it is shown in Fig (6), the highest values of metal released were obtained in the control soils (no sludge addition). On the other hand, the organic enriched soil with high rate of sludge addition showed less capability to release metals.

In conclusion, the total amounts of the metals recovered through release did not equal to the amount of the metals retained by the soils, which may suggest that at least one of the retention reactions was irreversible. Addition of sludge to sandy soil as an amendment could constrain the solubility and mobility of heavy metals contaminants and therefore the pollution of surface and ground water systems. However, The immobilized metal may become bioavailable with time through natural weathering processes or through advanced decomposition of soil organic matter.

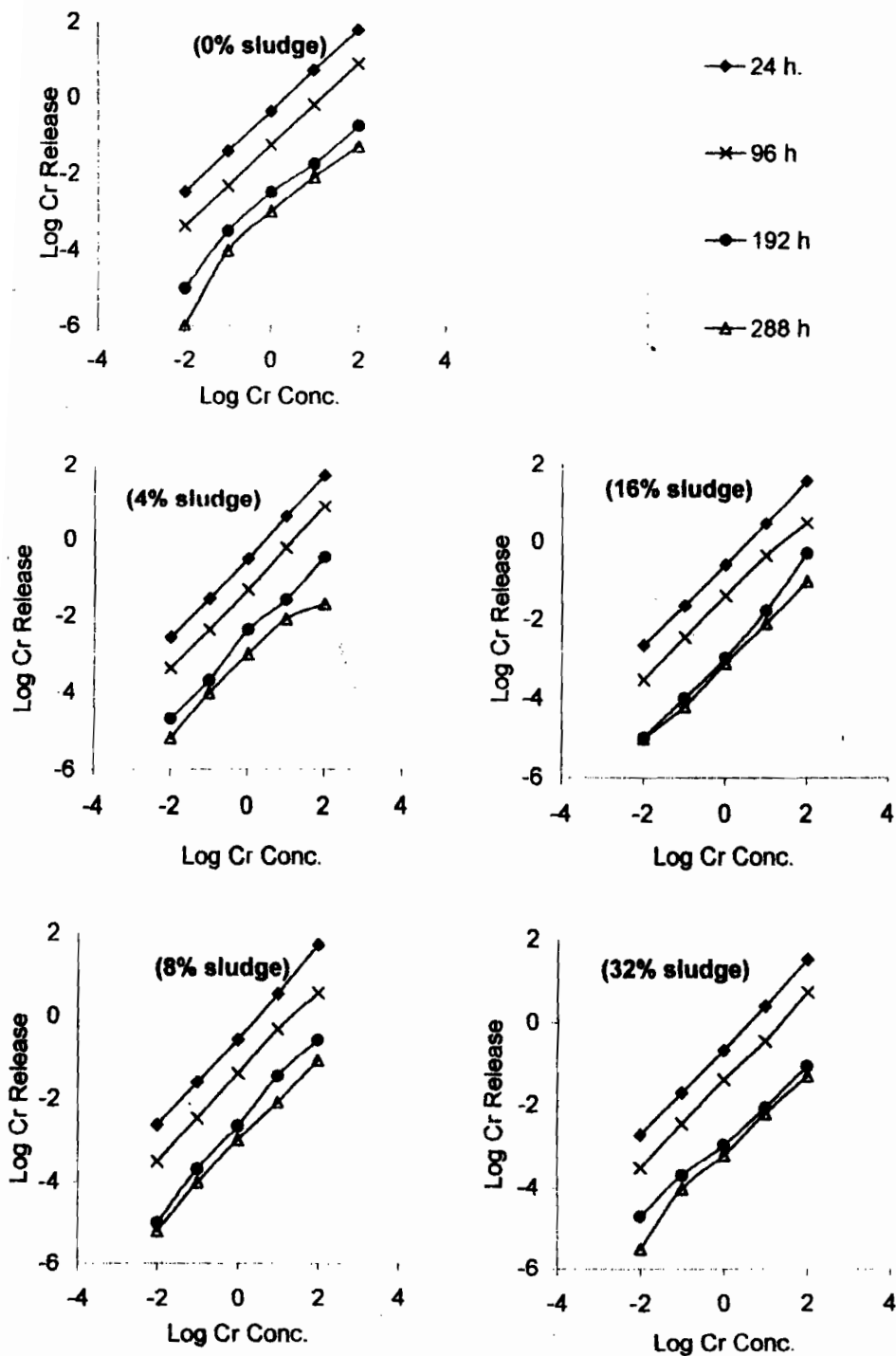


Fig.4. Logarithmic curves of Cr released from soil-sludge mixtures at different metal concentrations and different times.

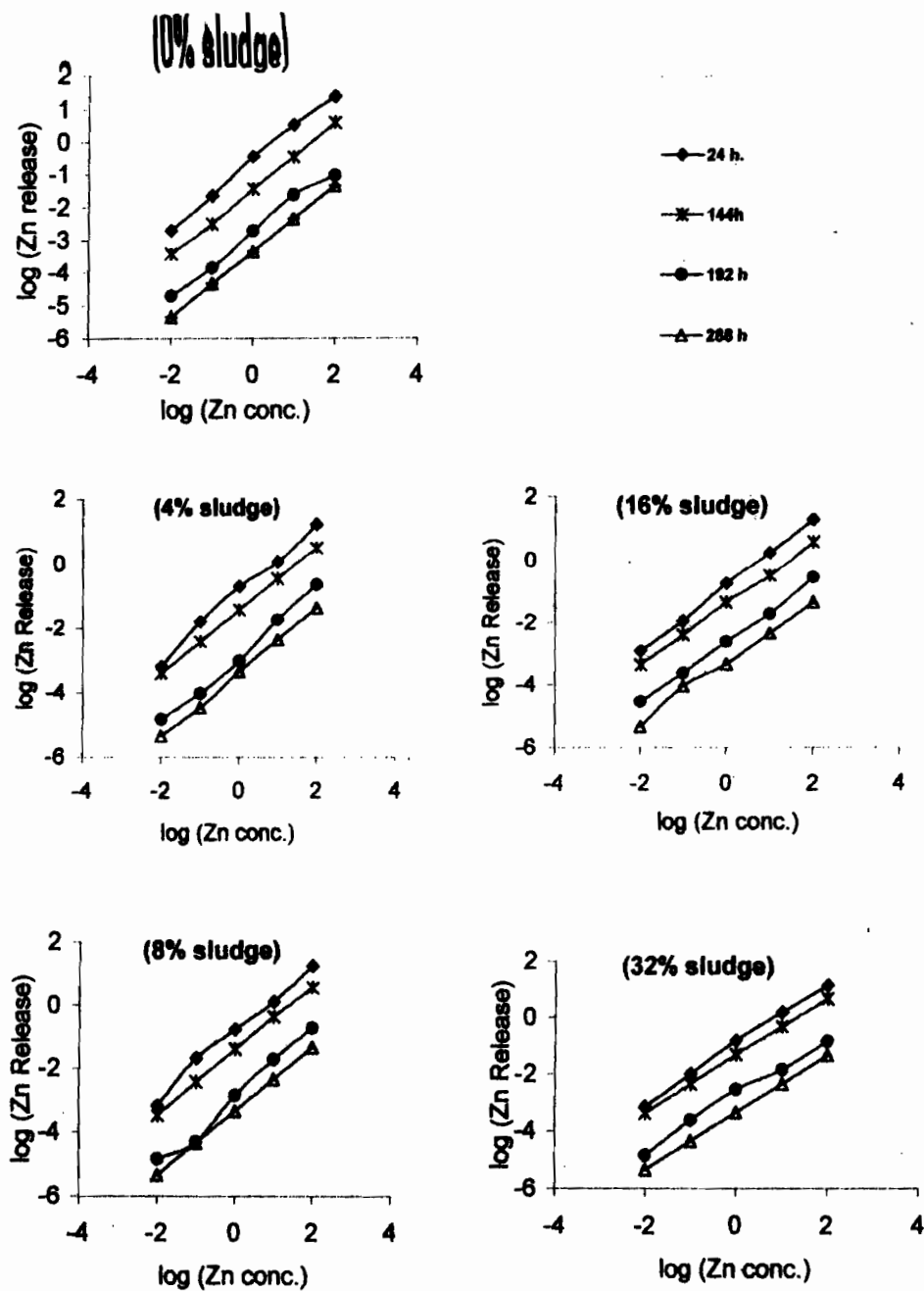


Fig. 5. Logarithmic curves of Zn released from the soil-sludge mixtures at different metal concentrations and different times.

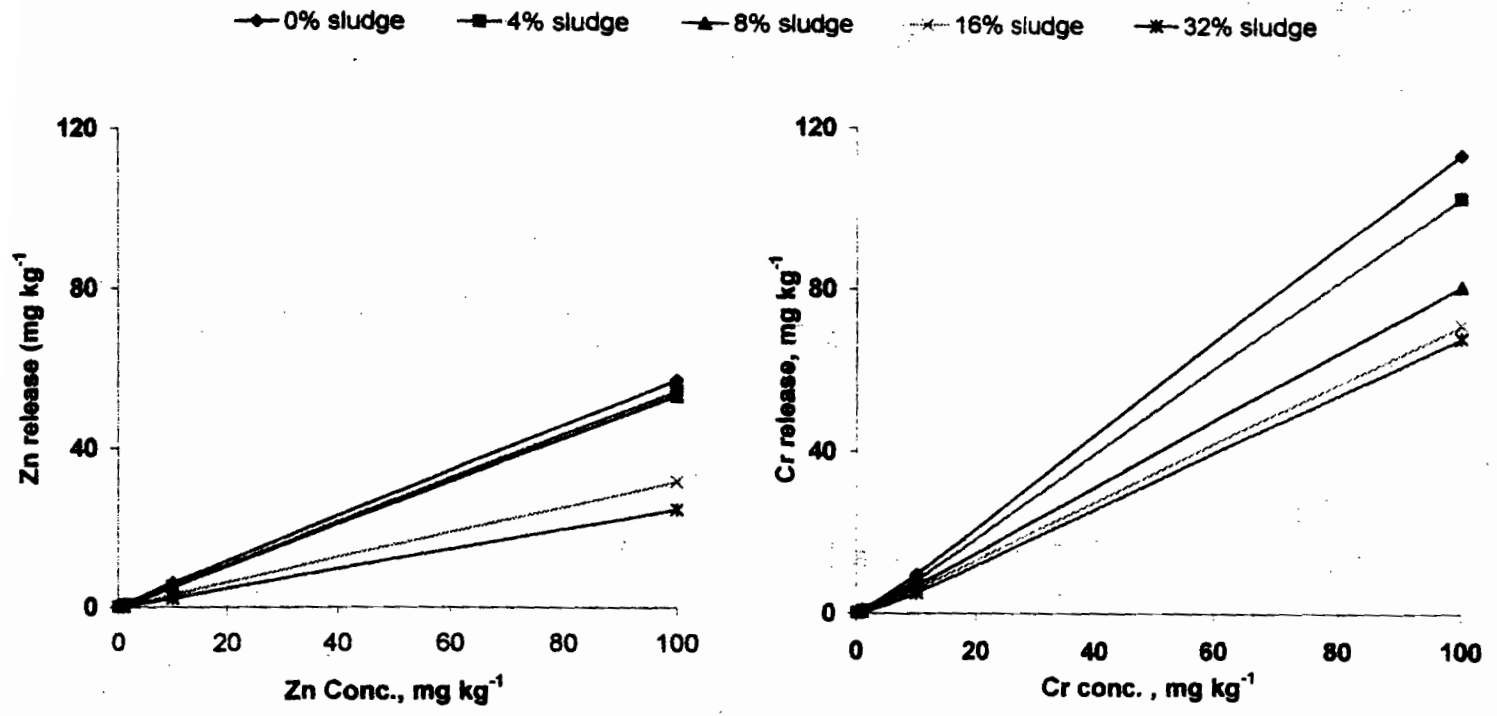


Fig. 6.Total release of zinc and chromium from the soil-sludge mixtures at different metals concentrations.

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*- قسم علوم الأراضى - كلية الزراعة - جامعة الزقازيق

**- قسم الأراضى والمياه - مركز البحوث النووية هيئة الطاقة الذرية

تعتبر اضافة الحماء المستخرجه من مخلفات الصرف الصحى و الصناعى الى الارض احدى الخيارات الهامه فى التعامل مع هذه المخلفات ، بغض النظر عن الاعتبارات البيئية على المدى البعيد ، لما تتمتع به هذه المواد من سعة امصاصيه عاليه بمجرد اضافتها الى الارض. و مع زيادة استخدام هذه المخلفات وبما تحتويه من عناصر سامه تعود اهمية دراسة محتوى هذه المواد من العناصر الثقيله وكذلك سلوكها فى الارض.

تهدف هذه الدراسة الى استخدام النظائر المشعة لعنصرى الكروميوم و الزنك (Cr^{51} , Zn^{65}) بتركيزات مختلفه لمعرفة قدرة احتجاز و انطلاق هذه العناصر فى ارض رملية اخنت من محطة بحوث هيئة الطاقة الذرية باتشاص وتم اضافة مخلفات الصرف الصناعى (الحماء) - المستخرجه من مصرف مسطرد- بمعدلات متزايدة (صفر، ٤، ٨، ١٦، ٣٢ % بالوزن) ، كذلك تهدف الدراسة الى ايجاد العلاقات المتبادله بين احتجاز و انطلاق هذين العنصرين. و محتوى الارض من الماده العضويه و السعة التبادليه الكتيونيه. وقد اوضحت النتائج ان اضافة الحماء بمعدلات متزايدة ادى الى زيادة محتوى الارض من الماده العضويه الى ثلاث اضعاف و بالتالى زيادة السعة التبادليه الكتيونيه. ايضا وجد ان زيادة زمن التلامس بين الارض و المحلول المحتوى على هذه العناصر الى ٣٣٦ ساعة لم يؤثر تأثير معنوى على قدرة الارض على احتجاز هذه العناصر. كما اوضحت منحنيات الامصاص المتحصل عليها مع جميع مخاليط التربه و الحماء المستخدمه تباينا فى درجة انحلالها، حيث كانت اكثر شدة فى التربه الغنية بالماده العضويه حيث لوحظ ان معدل لمصاص الزنك Zn^{65} تراوح من ١٦١ الى ٩٠٩ ملجم/كجم بينما معدل لمصاص

الكروميوم Cr^{51} تراوح من ٢٠٢ الى ١١١١ ملجم/كجم ، وان اعلى قيمة للامصاص لوحظت فى الاراضى التى اضيفت اليها الحمأه بمعدل مرتفع حيث المحتوى العالى من المادة العضويه. كذلك وجد ان هناك معامل ارتباط قوى بين تركيز العنصر المدمص على التربه و تركيز نفس العنصر فى المحلول ، و انه يلزم زمن قدره ٢٤ ساعه لكى يصل عنصر الكروميوم الى حالة الاتزان و مطابقا لمعادلة لانجمير. ايضا اوضحت قيم معامل طاقه الارتباط المتحصل عليها لكل من الزنك و الكروميوم المشع انخفاضا فى حالة الاراضى الرملية الغير مضاف اليها الحمأه ، حيث تراوحت القيم من ٠٠٠١٥ الى ٠٠٠٢١ ، بينما فى الاراضى الغنيه فى المادة العضويه و المضاف اليها الحمأه بمعدلات مرتفعه اعطت قيم عاليه وصلت الى ٠٠٠٠٣. كما لوحظ ان هناك علاقه موجبه بين عوامل معادله لانجمير وكل من محتوى الارض من المادة العضويه و السعة التبادليه الكاتيونييه. كذلك وجد ان الكمية المنطلقه من عنصرى الزنك و الكروميوم (Cr^{51} , Zn^{65}) عند فترات زمنيه مختلفه تتناقص مع الزمن ، و ان اكبر كميته منطلقه من هذه العناصر لوحظت فى الاراضى الفقيره فى المادة العضويه (الغير مضاف اليها الحمأه) بينما الاراضى المضاف اليها الحمأه ابدت قدره اقل على تحرير و اطلاق هذه العناصر المدمصه. الكمية المنطلقه من الزنك و الكروميوم لم تكن مساويه لتلك الكميته التى تم احتجازها فى الارض خاصة مع ارتفاع محتوى المادة العضويه ، كما ان الكميته المنطلقه من الكروميوم اكبر من الزنك.

فى النهايه يمكن استنتاج ان اضافة الحمأه كمحسن الى الاراضى الرملية قد يحد ويقيد من نوبتيه و حركة العناصر الثقيله و بالتالى يقلل من تلوث المياه الجوفيه و السطحيه بهذه العناصر، من ناحية اخرى ، فان هذه العناصر قد تصبح حرة الحركة مع مرور الزمن و ذلك من خلال عمليات التجويه او التحلل المتقدم للماده العضويه.