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HEAVY METALS CONTENT RELATING TO SOIL PHYSICAL PROPERTIES

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Key Words: Soil organic matter, Void ratio, Soil texture, Water holding capacity and heavy metals.

ABSTRACTS

Exception of iron, all heavy metals above a concentration of 0.1% in the soil become toxic to plants and therefore change the root Environment community structure of plants in a polluted habitat **(Ernst 1982).**

Soil contamination is generally attributed to degradation of its chemical and biological properties may be to physical properties as well. The present study was conducted to evaluate the effect of some soil physical properties, i.e. soil organic matter (OM), void ratio (VR), soil texture (clay %) and water holding capacity (WHC) on heavy metals content.

The achieved results could be summarized in the following:

Void ratio correlated significantly with organic matter and clay percent, as well as water holding capacity as all increased by increasing void ratio. Heavy metals, i.e. Mn and Ni concentration increased as a result of increasing soil organic matter while Fe has non significant relation. But, when organic matter coupled with other soil studied physical properties show a highly significant on Fe Concentration (R=0.908***) . Increase in clay percent led to increasing concentration of Ni while, Fe and Mn show a non significant relation. Also, all studied heavy metals increase significantly with increasing void ratio and water holding capacity.

INTRODUCTION

Heavy metals contamination of soils became a severe issue in agricultural production around the world in the past few decades as a result of anthropogenic activities, such as mining or industrial activities and improper use of heavy metal-enriched materials in agriculture, including chemical fertilizer and pesticides, industrial effluents, sewage sludge and wastewater irrigation **Ramadan and Al-Ashkar, 2007.**

Wastewater irrigation, solid waste disposal, sludge applications, vehicular exhaust and industrial activities are the major sources of soil contamination with heavy metals. The long term use of wastewater in agricultural land is resulting in the contamination of soils by heavy metals. These heavy metals include zinc (Zn), cadmium (Cd), copper (Cu), and nickel (Ni), lead (Pb), manganese (Mn), iron (Fe), mercury (Hg) and chromium (Cr). **Dougherty and Hall (1995)**

Excessive accumulation of heavy metals in agricultural soils through wastewater irrigation, may not only result in soil contamination, but also lead to elevating heavy metal uptake by crops, and thus affect food quality and safety **Costa, 2000**

High contents of heavy metals in soils would increase the potential uptake of these metals by plants. Therefore, a detailed risk assessment of heavy metal accumulation in agricultural lands is required for application of inorganic fertilizers, organic wastes and pesticides to soils in order to ensure the safe crop production **Papafilippaki et al., 2007.**

Heavy metals in soils may be present in several forms with different levels of solubility as follows: (i) dissolved (in soil solution),(ii) exchangeable (in organic and inorganic components), (iii) structural components of the clay lattices in soils and (iv) insolubly precipitated with other soil components **Aydinalp and Marinova, 2003.**

Usually, only the first two forms are able to be absorbed and utilized by plants. Therefore, plant uptake of a metal is mainly dependent on the metal mobility and availability in soils.

Generally, the mobility and availability of heavy metals are controlled by adsorption and desorption characteristics of soils **Krishnamurti et al., 1999.** The adsorption and desorption of heavy metals have been demonstrated to be associated with soil properties, including pH, organic matter content, cation exchange capacity (CEC), oxidation reduction status (Eh), the contents of clay minerals, calcium carbonate, Fe and Mn oxides **Antoniadis et al., 2008.** Among these soil properties, organic matter content in soil is also one of the most important soil properties affecting heavy metal availability.

Organic matter is a major contributor to the ability of soils for retaining heavy metals in an exchangeable form. In addition, organic matter also supplies organic chemicals to the soil solution that can serve as chelates and increase metal availability to plants, **McCauley et al., 2009.**

The role of organic matter on metal availability has been extensively investigated. It was reported that heavy metal adsorption onto soil constituents declined with decreased organic matter content as well as porosity and moisture content of soil **Hettiarachchi et al., 2003.**

Moreover, the dissolved organic matter in soils could increase the mobility and uptake of heavy metals to plant roots **(Du Laing et al., 2009). Dai et al. (2004)** estimated DTPA-extractable Zn content in heavy metal contaminated soils and also found that the contents of these metals were positively correlated with organic matter contents in soils.

Clay fraction, which is mainly composed of clay minerals, stands out because of its high potential to bind heavy metals. Soils having granulometric composition characteristic for clay, silt and dust, and those with a high content of organic matter, have a high sorption capacity and a strong ability to bind metallic elements. However, sandy soils, distinguished by a low sorption capacity which lead to their movement to groundwater, **Sheoran (2009)**

In viewing of the effect of soil physical properties on the concentration of heavy metals in soils, the current experiment was conducted to, (1). Determine concentration of iron (Fe), manganese (Mn), and nickel (Ni) in soil profiles. (2). Study the interrelation of all studied physical properties (3) Study the impact of Soil texture (clay), organic matter, and water holding capacity and void ratio on heavy metals retention in soils.

MATERIAL AND METHODS

1:-Soil Sampling and Preparation for studies.

Five Soil profiles were selected from Cultivated Desert Soils in 10^{th} of Ramadan region. Fifteen (15) soil samples collected from the subsequent layers of the studied profiles were air dried and lumps were crushed with a wooden pestle in a wooden mortar so that the aggregate particles were dispersed but no actual grinding takes place. The soil samples were then sifted through a sieve with round holes of 2mm diameter, stored in air - tight polyethylene bottles, and kept for analysis and experimental work.

2:- Soil sampling analyses:

Physical analysis:

Mechanical analysis was carried out by the international pipette method of **Kilmer and Alexander (1949)** in which sodium hexameta - phosphate is used as a dispersing agent. Void ratio and water holding capacity (WHC) according to special design of keen and Rashkovisky.

Chemical analysis:

Organic matter content was determined by the method outlined by **Jackson (1973).** Determination of pH in the soil extract was carried out by Beckman glass electrode pH – meter. **Black (1983).** Electrical conductivity (EC) of the soil saturation extract determined following the methods described by **Jackson (1973).** Cation exchange capacity (CEC) and exchangeable cations were determined following the methods described by **Jackson (1973).** Total heavy metals contents in soils under study (Fe, Mn and Ni) were determined by the Ionic Coupled Plasma, after digestion of the samples with a ternary acids mixture of HNO_3, H_2SO_4 and $HClO_4$.it is recommended by **Hesse (1971).**

RESULTS AND DISCUSSION

Soils could be contaminated with heavy metals as a result of failure of some soil physical properties as texture (clay percent), soil organic matter (OM), moisture and void ratio **Cynthia et al (1997).** Therefore, the main target of this study is to evaluate these characters and declare how much the effect on heavy metals behavior under study. The data present in tables (1&2) indicate the found results of physical properties for the studied samples.

Interrelations among the studied physical properties:

There is a strong relationship among clay content, OM content, void ratio and WHC and it is likely that these factors influence each other synergistically **(Evelyn et al 2006).** Increasing soil organic matter content increased aggregation and decreased D_b, which tend to increase the total pore space as well as the number of small pores. In turn, soil void ratio and water holding capacity increased **(Haynes and Naidu, 1998).** Table (1&2) point out that, increasing soil organic matter and clay content resulted in increasing void ratio by44% as the difference between the maximum and minimum values of columns, this result assured by linear relation shown in Fig (1), and the simple correlation values were, r_1= 0.891**, r_2= 0.681* for organic matter and clay content, regarding the coefficients of organic matter and clay content it declare that each 1% increasing in organic matter or clay increased void ratio by 40% with the former and 0.4% with the later, respectively. Moreover, water holding capacity increased by increasing void ratio Table (1) and Fig (1) this increase reached 90%, where the simple correlation was 0.583*. These results agree with **Kay et al.'s (1997)** who found that increased organic carbon by 0.01g per gram of soil, WHC can be increased by up to 30%, depending on clay content.

Effect of soil physical properties on heavy metal content.

Effect of Organic matter (OM):

Soil organic matter increases with depth for profile (1, 2) layers where texture is sandy, whereas it decreases with depth, as for the rest soil textures of sandy loam or loamy sand (Table 1).

Table (1). Some physical and chemical characters of studied profiles.

Profile No.	Depth Cm	pH	CEC meq/100g soil	OM %	VR	WHC	Moisture %		
							FC	WP	AM
1	0-30	6.98	4.06	0.17	30.18	23.12	1.27	0.13	1.14
	30-60	8.17	3.68	0.23	31.55	24.22	1.29	0.13	1.16
	60-90	7.54	4.08	0.41	41.19	40.17	1.28	0.11	1.17
2	0-30	7.35	4.10	0.35	35.22	33.22	1.27	0.12	1.15
	30-60	7.43	4.52	0.36	35.40	33.22	1.28	0.10	1.18
	60-90	7.32	4.46	0.40	41.33	40.12	1.74	0.24	1.50
3	0-30	7.11	7.43	0.41	42.11	22.13	1.81	0.15	1.66
	30-60	7.20	3.86	0.35	36.21	40.12	1.72	0.17	1.30
	60-90	7.14	3.96	0.12	31.25	33.22	1.24	0.12	1.31
4	0-30	7.03	4.74	0.39	36.88	35.40	1.71	0.23	1.48
	30-60	7.15	4.66	0.28	32.46	25.50	1.73	0.23	1.50
	60-90	6.79	5.22	0.23	31.54	24.22	1.25	0.11	1.14
5	0-30	8.68	4.04	0.35	35.90	33.33	1.68	0.25	1.43
	30-60	7.07	5.58	0.46	43.71	42.22	1.78	0.26	1.61
	60-90	7.08	5.08	0.31	32.77	31.22	1.41	0.18	1.23

Where: *OM* is organic matter, *VR* is void ratio, *WHC* is water holding capacity, *FC* is field capacity,
***WP* is wilting point and *AM* is available moisture**

Table (2).Particle size distribution and textual classes of studied profiles.

Profile No.	Depth, cm	Soil fractions (mm %)				Textual class
		Coarse sand	Fine Sand	Silt	Clay	
1	0-30	65.08	32.04	1.52	1.36	Sand
	30-60	63.61	33.84	1.09	1.46	Sand
	60-90	65.16	32.07	1.26	1.51	Sand
2	0-30	66.12	32.28	0.23	1.37	Sand
	30-60	58.97	38.97	0.21	1.85	Sand
	60-90	63.78	13.94	4.17	18.1	Loamy Sand
3	0-30	49.47	20.18	11.1	19.25	Sandy loam
	30-60	69.21	8.75	16.02	6.02	Loamy sand
	60-90	75.09	24.21	0.15	0.55	Sand
4	0-30	33.82	49.81	2.17	14.2	Loamy sand
	30-60	60.68	12.54	12.6	14.18	Loamy sand
	60-90	68.47	30.18	0.33	1.02	Sand
5	0-30	58.69	23.2	8.02	10.09	Loamy sand
	30-60	33.83	40.1	8.01	18.06	Loamy sand
	60-90	16.84	80.77	0.3	2.09	Sand

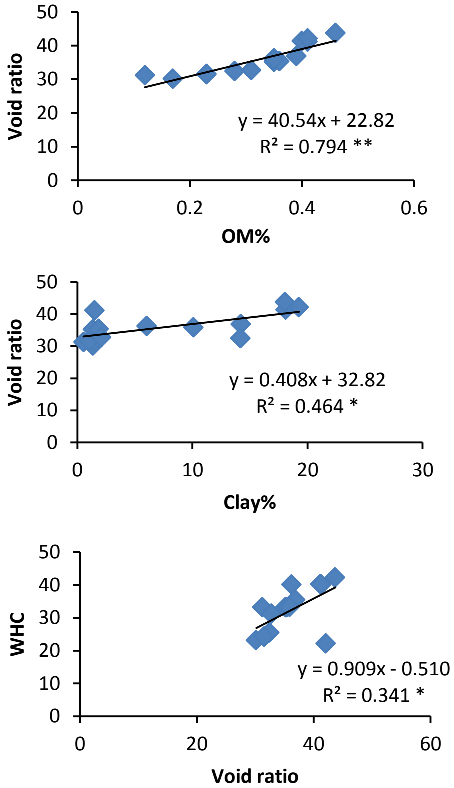

Fig (1) soil physical study interrelation.

Generally, all soil profiles shown in tables (1and 3) indicated that both Mn and Ni concentration values increased as a result of increasing soil organic matter, as these values reached 207 and 396% for Mn and Ni respectively as comparing the maximum and minimum values. In addition, from values of Mn and Ni concentration increased by depth for profile 1 and 2, while for profile 5 is not that as the whole OM content is high. For profiles 3 and 4 contrariwise behaviors is noticed. Meantime, Fe show no significant increased with organic matter whether, fig (2) emphasizes the simple linear relations of soil organic matter and heavy metals and, the simple correlation values were r= 0.428^{Ns}, r = 0.567^{*} and r= 0.675^{*} for Fe, Mn and Ni Respectively, when organic matter coupled with other studied physical properties led to a high significant relation with Fe concentration where multiple correlation and regression were: R = 0.908*** and Fe = -19945.9+ 642.7 VR+391.6 WHC – 35305 OM-228.6Clay

Table (3). Heavy metals concentration in ppm

Profile No.	Depth cm	Heavy metals in ppm		
		Fe	Mn	Ni
1	0-30	999.1	55.2	2.88
	30-60	1555	57.9	4.28
	60-90	8120	80.25	14.29
2	0-30	2100	55.30	8.75
	30-60	2740	56.12	9.33
	60-90	3322	62.00	11.99
3	0-30	5777	125	14.165
	30-60	4400	44.25	7.33
	60-90	4300	43.85	9.29
4	0-30	2010	95.2	8.65
	30-60	1325	55.4	8.25
	60-90	790	36.2	4.50
5	0-30	1850	88	5.1
	30-60	3650	125	12.75
	60-90	1550	135	7.13

Toxic limits Fe (> 500 mg kg^{-1}). Mn (> 20 mg kg^{-1}).Ni (>0.1 mg kg^{-1}). Kabata-Pendia (2000).

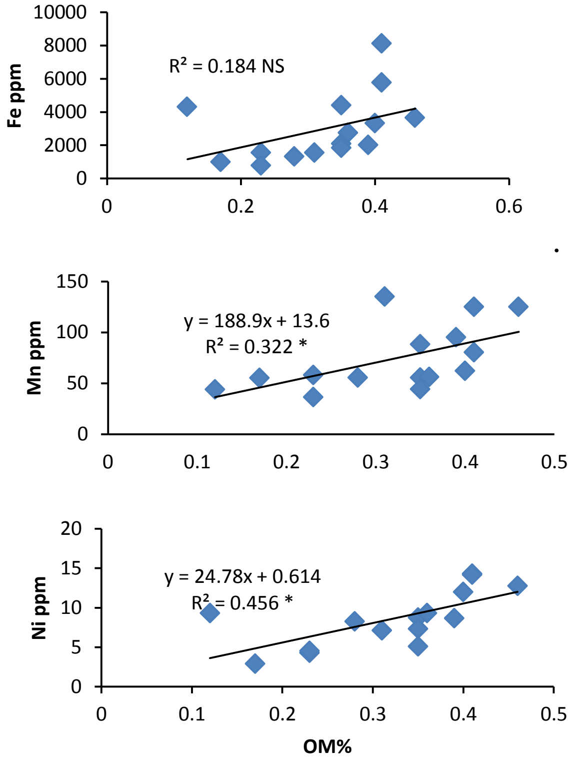

Fig (2) heavy metals concentration in ppm affected by soil organic matter.

These results agree with **McCauley et al., (2009).** However, **Ociepa et al (2010)** explain this phenomenon as increasing the amount of organic matter in the soil helps to minimize the absorption of heavy metals by plants; organic matter actively retains heavy metals by binding as complex compound, Sorption capacity of organic matter is above the mineral sorption capacity of the soil

Effect of soil texture:

Mechanical composition of soil is one of the important factors determining the extent of soil contamination with heavy metals and their content in plant tissues. Clay fraction, which is mainly composed of clay minerals, stands out because of its high potential to bind heavy metals. However, sandy soils, distinguished by a low sorption capacity and acidity, weakly absorb heavy metals, which lead to their movement to groundwater, **Krzysztof et al. (2012)**

Data in table (2) reveal that profiles texture varied from sandy to sandy loam and loamy sand with different clay content implying that there are differences in CEC and porosity. Therefore, increase in clay percent led to significant increasing Ni concentration in soil profiles, while Fe and Mn show no significant relation Tables (2 and 3). Furthermore, fig (3) come to assure these relation and the simple correlation values were r= 0.145^{Ns}, r= 0.487^{Ns} and r= 0.511* for Fe, Mn and Ni by the same sequence. This result agrees with those obtained by **Antoniadis et al., 2008 and Sheoran et al. (2009).**

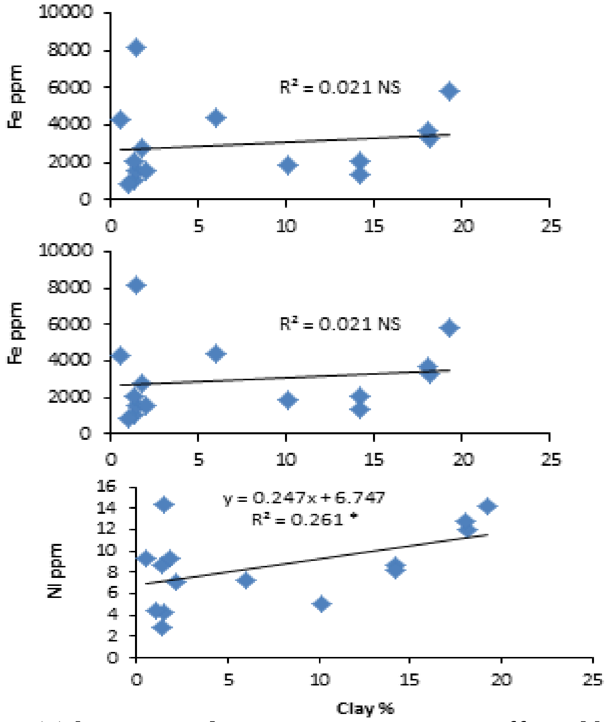

Fig (3) heavy metals concentration in ppm affected by clay percent.

Effect of void ratio (VR):

Void ratio is important in raising concentration of heavy metals and expresses the clay percent and variety, percent of organic matter and total porosity volume which retain heavy metals. So, studying this variable means understanding how soil becomes polluted. Tables (1and 3) point out that concentration of studied heavy metals increase significantly with increasing void ratio. Fig (4) illustrates the linear relation and regression equations among void ratio and heavy metals concentration. The correlation values were r=0.664*, r=0.536* and r= 0.848* for Fe, Mn and Ni respectively.

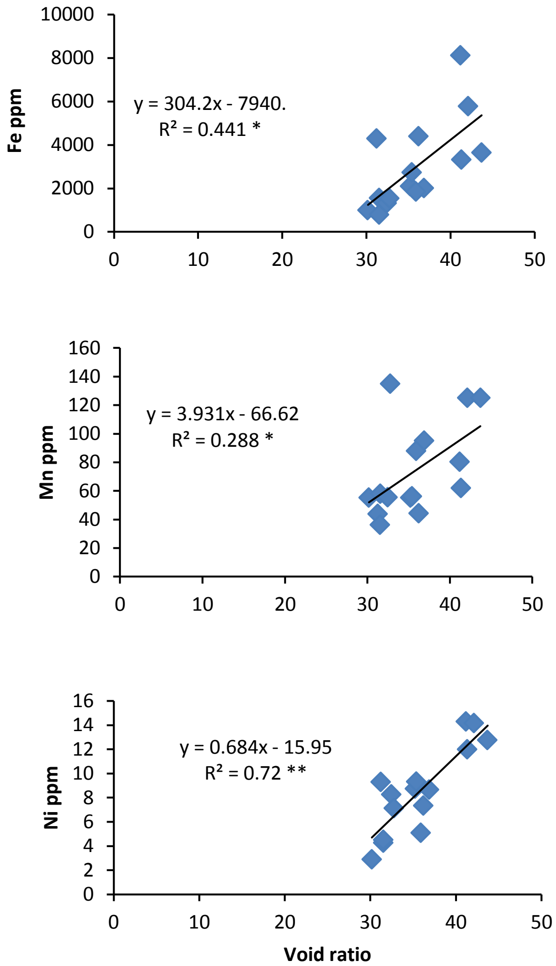

Fig (4): heavy metal concentration in ppm affected by soil void ratio.

Effect of water holding capacity (whc):

Water holding capacity means how much water retentive by soil thus a quantity of heavy metals, tables (1, 3) represent the relation between water holding capacity and heavy metals concentration where, all studied heavy metals increased by increasing water holding capacity. Also, fig (5) shows a linear relations for previous studied variables and regression equations while simple correlation values are as follow r=0.511*, r=0.566* and r=0.767** for Fe, Mn and Ni by the same sequence. This result agreement with finding by **Hettiarachchi et al., 2003.** The opposite result obtained by **Rakesh and Raju 2013.**

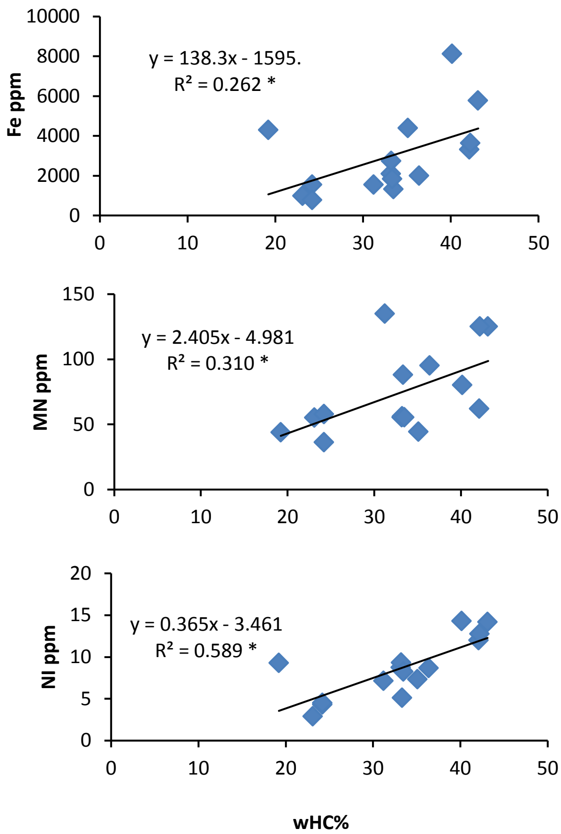

Fig (5) heavy metals concentration in ppm affected by water holding capacity ratio.

CONCLUSIONS

Mobility and Retention of heavy metals is a vital step in soil pollution and persistence in the environment. Soil physical properties degradation can be considered as a viable source for the contamination by heavy metals. However, there is a need to up-date the knowledge base on the influence of soil properties as well as the physic-chemical system properties on the studied heavy metals absorbed in order to develop optimized soil properties to remove heavy metals. Based on the previous results we can conclude the following: there is interrelation between studied physical properties, resulted in increase retentively of heavy metals for all profile types. Organic matter occurring is favorable for identify how much heavy metal removed from soil solution can prevent them from reaching plant roots, soil pollution limited by quantity of soil organic matter and clay which affected directly on cation and anion exchange capacity, void ratio and water holding capacity.

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محتوي العناصر الثقيلة نسبة الى خصائص الأرض الطبيعية

مجدى حسن ذكى – عبد السلام محمد علوه

مركز بحوث الصحراء

يعزى تلوث الأراضى عموما الى تدهور خصائصها الكيماوية والحيوية وايضا الى تدهور خصائصا الطبيعية . وتهدف الدراسة الحالية الى تقييم تأثير بعض خصائص الارض الطبيعية مثل (المحتوى العضوى– الفراغ الجوفى– القوام– السعة المائية) على الأحتفاظ بالعناصر الثقيلة المدروسة.

وكانت النتائج كما يلى:

ارتبط الفراغ الجوفى للتربة معنويا بمحتوى التربة من المادة العضوية ونسبة الطين كما زادت السعة المائية بزيادة الفراغ الجوفى. زاد تركيز المنجنيز والنيكل بزيادة المادة العضوية فى حين اظهر الحديد زيادة غير معنوية، وادت معاملة الخلط بين الخصائص المدروسة الى معنوية عالية مع الحديد. وجدت علاقة معتوية بين الطين والنيكل وغير معنوية مع الحديد والمنجنيز. كل العناصر الثقيلة المدروسة اظهرت ارتباطا معتويا مع كل من الفراغ الجوفى والسعة المائية.